Street Tree Growth Rates and Benefit-Cost Quantification[1]

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Abstract: This study answers the question: *Do the accrued benefits from Modesto's urban forest justify an annual municipal budget that exceeds $2 million?* Results indicate that the net benefits from Modesto's 91,179 public trees exceed management costs by a factor of nearly 2 and totaled $2,329,900 ($12.76/resident, $25.55/tree). Due to the tree population's relatively even-aged structure and heavy reliance on mature Modesto ash for benefits, management strategies are needed that may reduce net benefits but increase diversity and stability.

Located in Northern California, Modesto has a population of 183,000 and needs to grow to maintain a vigorous local economy. However, the city's ability to grow is influenced by environmental constraints and competition with other regions in terms of quality of life. Research indicates that healthy city trees can mitigate impacts of development on air quality, climate, energy for heating and cooling buildings, and stormwater runoff. Healthy street trees increase real estate values, provide neighborhoods with a sense of place, and foster psychological well-being.

However, in an era of dwindling public funds and rising expenditures there is need to scrutinize expenditures often considered "non-essential" such as planting and management of the municipal forest.

Although the current program has demonstrated its efficiency, questions remain regarding the need for the level of service presently provided. Hence, the primary question that this study asks is: *Do the accrued benefits from Modesto's urban forest justify an annual municipal budget of over $2 million?* In answering this question our purpose is to:

- Assist decision-makers to assess and justify the degree of funding and type of management program appropriate for this city's urban forest.
- Provide critical baseline information for the evaluation of program cost-efficiency, alternative pruning cycles, and alternative management structures.
- Highlight the relevance and relationship of Modesto's urban forest to local quality of life issues such as environmental health, economic development, and psychological well-being.
- Provide quantifiable data to assist in developing alternative funding sources through utility purveyors, air quality districts, federal or state agencies, legislative initiatives, or local assessment fees.

Methods

Modesto's street tree inventory database contains 75,649 trees and 184 species. We sampled 648 street trees belonging to 22 of the most abundant species in Modesto to 1) establish relations between tree age, size, leaf area and biomass for important species, 2) estimate growth rates, and 3) collect other data on tree health, site conditions, and sidewalk damage. The number of trees belonging to the species sampled accounted for 92% of the entire

street tree population. We measured diameter at breast height (dbh), tree and bole height, crown radius, tree condition and location, severity of pruning, and site index. Crown volume and leaf area were estimated from computer processing of digital images of tree crowns and then tree leaf area, crown diameter, and tree height were calculated using regression models.

To infer from the 22 species sampled to the remaining 162 species, called Other Street Trees, we categorized each species based on life form and mature size. We estimated the total number of park trees by tree type category from a sample inventory. Lacking data on the age of park trees, we assumed that park and street trees were similarly distributed among age classes within each tree type.

Annual Costs

Expenditures reported by the Community Forestry Division during fiscal year 1997-98 were used in this study. Tree related expenses captured by other departments for sidewalk and curb repair, leaf clean-up, and claims were also included.

Annual Benefits

Annual benefits were estimated for 1998 using methods summarized below and described in detail in a published paper and technical report (McPherson et al. 1999a, b). Growth rate information was used to "grow" the tree population for one year. Lacking detailed information on tree species planted and removed over the course of the year, we assumed that population numbers remained constant and accounted for annual benefits from the existing population. Our approach directly connected benefits with tree size variables such as dbh and leaf surface area. Many functional benefits of trees are related to leaf-atmosphere processes (e.g., interception, transpiration, photosynthesis), and therefore benefits increase as tree canopy cover and leaf surface area increase.

Prices were assigned to each benefit through direct estimation and implied valuation of benefits as environmental externalities. Findings from aerial photo analysis of street tree shade on buildings and computer simulations were used to directly estimate energy savings. Numerical models were used to estimate annual benefits associated with atmospheric carbon dioxide reductions, stormwater runoff reductions, air pollutant uptake, and aesthetic and other benefits. Implied valuation was used to price society's willingness to pay for air quality, hydrologic, and other benefits trees produce. For example, air quality benefits were estimated using transaction costs that reflect the average market value of pollutant emission credits from 1994-97 for the San Joaquin Valley Unified Air Pollution Control Management District. If a corporation is willing to pay $1/kg for a credit that will allow it to increase future emissions, then the air pollution mitigation value of a tree that absorbs or intercepts 1 kg of air pollution should be $1.

Findings
Tree Population Characteristics

There were approximately 91,179 public trees in Modesto, or one public tree for every two residents. Street trees accounted for 83% (75,629) of the total, while park trees comprised the remaining 17% (15,550).

In Modesto there were an average of 82 trees/km of street (113/mile). Average street tree spacing was 24 m (80 ft) on each side of City streets. The stocking level was 62% of full stocking (15 m or 50 ft spacing). Modesto's stocking level is very high compared to the mean stocking of 38% found for 22 U.S. street tree populations (McPherson and Rowntree 1989). Modesto ash (*Fraxinus velutina* 'Modesto') was the most common street tree species, with over 10,000 trees accounting for 14% of the population. However, because 85% of Modesto ash were planted more than 45 years ago their large size makes them especially important.

The age structure for all public trees in Modesto had a relatively even distribution of trees among age classes. Trees less than 10 years old accounted for only 20% of the population compared to the "ideal" of 40%. The pattern suggests that a large number of trees were planted from 1960 to 1985 to fill out Modesto's urban forest. Tree canopy cover for the entire City was 31%, and street and park tree canopy covered 8.3% of the entire City.

Modesto's street trees shaded approximately 30% of all street paving. Overall, the municipal urban forest appeared healthy.

Annual Costs
Total fiscal year 1997-98 net expenditures totaled $2,623,384 ($14.36/resident, $28.77/tree). This amount represents 2% of the City's total operating budget ($123.1 million). Mature tree care comprised $1.7 million of the tree program's budget and inspection and pruning accounted for 69% of this amount or $1.1 million. The Division removed 1,300 trees at a cost of $343,000. Clean-up after storms cost $5,000. To protect sidewalks and private property from damage the tree program spent approximately $85,000 for root pruning and installation of root barriers. Approximately $68,000 was spent on Integrated Pest Management. Administration costs totaled $316,000 Tree establishment activities (i.e., planting, irrigation, basin repairs, nursery) cost $271,000.

Expenditures external to the Community Forestry budget during FY 1997-98 included $297,586 spent on sidewalk and curb repair. The cost for leaf clean-up was estimated as $106,426. Expenditures for property claims averaged $26,000 annually. The average annual payment for all tree-related trip and fall claims was $42,000.

The Community Forestry Division received revenue for services totaling $63,132. Revenue sources included service credits ($10,132) for tree planting and care, fees collected from developers to cover the cost of planting trees in new subdivisions ($46,000), and line clearance work ($7,000).

Annual Benefits
Total benefits produced during 1998 by Modesto's street and park trees were estimated to have a value of nearly $5 million, about $27/resident. The average annual benefit per tree was $54 ($54/street tree and $57/park tree). Street trees produced benefits valued at about $4 million, while park tree benefits were valued at $890,000 and represented 18% of total benefits. Urban forest impacts on aesthetics and other benefits accounted for 29% of total benefits ($16/tree). Air quality benefits were of similar magnitude. Benefits associated with energy savings repre-

sented 20% ($11/tree) of total benefits. Stormwater runoff reductions and atmospheric CO_2 reductions accounted for 12% ($7/tree) and 9% ($5/tree) of estimated total annual benefits, respectively.

Modesto ash comprised 14% of all street trees and accounted for 22% of all street tree benefits by virtue of their size and numbers. Chinese pistache (9%), Chinese hackberry (9%), and Moraine ash (6%) were also important producers of benefits. Old trees, those greater than 40 years old, were about 20% of the population but produced 32% of all benefits ($1.6 million). Their average annual per tree benefit was $96. Modesto ash alone accounted for 47% ($753,000) of total annual benefits from old street trees. Relying on a single species species for such a large portion of total benefits is risky.

Trees less than 20 years old made up 40% of the tree population but were responsible for only 23% of total benefits. The magnitude of future benefits depend on the extent to which these young trees grow older and larger. Mature trees, trees 20-40 years old, comprised 40% of the population and accounted for 46% of total benefits ($2.3 million). Moraine ash, Chinese pistache and Chinese hackberry each produced benefits in excess of 10% of total benefits produced by all 20-40 year old street trees.

Net Benefits and Benefit-cost Ratio
Total fiscal benefits of $4,964,000, less net expenditures of $2,623,000 resulted in a net annual benefit of $2,340,000. Average annual net benefits per resident and per tree were $13 and $26, respectively. The benefit-cost ratio was 1.89, meaning that for each $1 in net expenditures for urban forest management, benefits valued at $1.89 were returned to the residents of Modesto.

Conclusion
The Modesto tree population has a relatively even-age structure, indicating fewer young, replacement trees and more old, overmature trees than "ideal". Given this age structure it is not surprising that expenditures for mature tree care comprise 74% of the Community Forestry Division's expenditures. Substantial funds are spent addressing other mature tree-related issues such as sidewalk repair, root

pruning, and trip and fall claims. Because of the existing forest's even-aged structure and reliance on benefits from Modesto ash, spending less on management at this time could jeopardize the future stream of net benefits.

Modesto's investment in urban forestry is providing tangible air quality, flood control, energy conservation, and CO_2 reduction benefits. The sources of these benefits suggest potential new partners in urban forest management. The local air quality and stormwater management districts, electric utility, and industry could view Modesto's urban forest as an asset to their programs. As air pollution trading markets develop there is potential for the City to claim credits for these benefits. Money obtained from the sale of credits could help finance the tree program. Pollution trading markets exist for several criteria pollutants (PM_{10}, NO_2, VOCs), and have been proposed for CO_2.

Looking toward the future, it may not be possible to maintain the high level of net benefits produced today by Modesto's municipal forest while at the same time increasing its stability. Creating a more stable forest may be a more appropriate goal than maximizing net benefits if it reduces the risk of catastrophic loss and lowers management costs on a per tree basis. Achieving a more stable forest will challenge management because of the forest's current structure.

Modesto's municipal urban forest reflects the values, lifestyles, preferences, and aspirations of current and past residents. It is a dynamic legacy, on one hand dominated by trees planted over 40 years ago and at the same time constantly changing as new trees are planted and others mature. It is an urban forest in transition. Planning and managing the transition from a relatively fragile forest to one that is more diverse and stable will require careful thinking, powerful analysis tools, and new partners.

END NOTES

[1] The complete version of this paper can be found in:

McPherson, E.G., Simpson, J.R., Peper, P.J., and Xiao, Q. 1999. "Benefit-cost analysis of Modesto's municipal urban forest." Journal of Arboriculture. 25(5):235-248.

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ACKNOWLEDGMENTS