A MODEL OF URBAN FOREST SUSTAINABILITY: APPLICATION TO CITIES IN THE UNITED STATES

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Abstract. The applicability of a model for urban forest sustainability was evaluated through a written survey. The model considers the character of the vegetation resource, community awareness of, and attitudes about, urban forests, and the management programs for the resource. Results from 25 U.S. cities were evaluated using the 20 criteria and four levels of performance found in the model. Although surveys were sent directly to mayors, urban forestry professionals completed the questionnaires. The average score for responding cities was 48.8, out of a maximum score of 80. The range in scores was 27 to 61. Criteria of sustainability with highest overall scores dealt with awareness of trees as a community resource and neighborhood action; the lowest scores involved the participation of private landholders in urban forest management and regional cooperation.

Creation and management of urban forests to achieve sustainability is the long-term goal of urban foresters as well as elected officials, business leaders, and citizens. Clark et al. (1997) previously described a model for assessing a community's progress towards this goal. In their model, a sustainable urban forest was defined as "the naturally occurring and planted trees in cities which are managed to provide the inhabitants with a continuing level of economic, social, environmental and ecological benefits today and into the future." The model considers three broad categories:

- Vegetation Resource: knowledge of the existing tree resource
- Community Framework: interaction and cooperation of constituent groups
- Resource Management: current management programs

To assess progress towards a sustainable urban forest, communities must have criteria to measure the current state of these three components. Historically, any such criteria have been qualitative in nature and lacked universal applicability. In the 1996 State of the Urban Forest Report (Sacramento Urban Forest Task Force 1996) for the Sacramento region, sustainability was assessed qualitatively, through 16 regionally specific criteria. In an approach focused on municipal programs, Thompson et al. (1994) identified four criteria of sustainable urban forests with a variety of qualitative assessment measures. In contrast to these examples, the model developed by Clark et al. provided a method of assessment that was region-independent and quantitatively based (Table 1). This paper presents an evaluation of the applicability of this model based upon the results of a survey of cities across the United States.

Methods and Materials

A written survey was developed that adapted the criteria of sustainability and performance indicators identified by Clark et al. (1997) into a series of open- and close-ended questions. In the open-ended questions, respondents were asked to provide opinions, examples, and experiences. In the close-ended questions, the possible responses corresponded directly to the four levels of performance suggested for each criteria of sustainability. For example, one of the criteria in the Community Framework component is the interaction among citizen, government, and business groups. The performance indicators of this criterion are as follows:

- Optimal: formal interaction (such as tree board with staff coordination)
- High: informal and/or general cooperation
- Moderate: no interaction among constituencies
- Low: conflicting goals among constituencies

In the survey, the question corresponding to this criterion was, "What is the level of interaction among government, citizens, institutions, corporations, and other constituent groups?"

Respondents could choose from among the following answers:

- Excellent, we have regular interaction (formal working group, city tree board, mayor's advisory committee, etc.).
- We have a tree board with communitywide representation, but it is not supported by city staff.
- Good, we have many informal contacts throughout the city.
- Fair, we have good interaction with some, conflicts with others.
- There is little interaction.
- Various groups are often in conflict.

Respondents were also asked, "Are there particular issues or topics that foster interaction

Table 1. Criteria for urban forest sustainability. Each criterion includes four levels of performance towards attaining the key objective (Clark et al. 1997).

Component	Criteria	Key objective
Vegetation Resource	Canopy cover	Achieve climate-appropriate degree of tree canopy communitywide.
	Age distribution of trees in community	Provide for uneven age distribution.
	Species mix	Provide for species diversity.
	Native vegetation	Preserve and manage regional biodiversity. Maintain the biological integrity of native remnant forests. Maintain wildlife corridors to and from the city.
Community Framework	Public agency cooperation	Ensure all city departments operate with common goals and objectives.
	Involvement of large private and institutional landholders	Large private landholders embrace citywide goals and objectives through specific resource management plans.
	Green industry cooperation	The green industry operates with high professional standards and commits to citywide goals and objectives.
	Neighborhood action	At the neighborhood level, citizens understand and participate in urban forest management.
	Citizen-government-business interaction	All constituencies in the community interact for the benefit of the urban forest.
	General awareness of trees as community resource	The general public understands the value of trees to the community.
	Regional cooperation	Provide for cooperation and interaction among neighboring communities and regional groups.
Resource Management	Citywide management	Develop and implement a management plan for trees and forests on public and private property.
	Citywide funding	Develop and maintain adequate funding to implement a citywide management plan.
	City staffing	Employ and train adequate staff to implement citywide management plan.
	Assessment tools	Develop methods to collect information about the urban forest on a routine basis.
	Protection of existing trees	Conserve existing resources, planted and natural, to ensure maximum function.
	Species and site selection	Provide guidelines and specifications for species use, on a context-defined basis.
	Standards for tree care	Adopt and adhere to professional standards for tree care.
	Citizen safety	Maximize public safety with respect to trees.
	Recycling	Create a closed system for tree waste.

among groups? that inhibit interaction among groups?"

Forty-five cities in the United States were identified as potential participants in the survey. Participant cities were selected based upon the following criteria:

- population between 30,000 and 750,000 (Chicago, Illinois, was an exception)
- geographic diversity, including natural forest diversity
- membership in U.S. Conference of Mayors
- active involvement with the programs of the Trust for Public Land
- existing municipal urban forestry program or nonprofit group

Surveys were sent directly to the mayor of each city, with a cover letter from the Conference of Mayors. Communities that did not return surveys within the designated completion period were contacted and encouraged to complete the survey.

Survey responses were converted to numerical scores based upon specific indicators of performance (i.e., no or negative response = 0, low = 1, fair = 2, high = 3, optimal = 4). Half-units (e.g., 2.5) were used in some cases. For example, in the question dealing with interaction among constituent groups scores were assigned as follows:

Response	*Score*
Excellent, we have regular interaction...	4
We have a tree board with community-wide representation...	3.5
Good ...	3
Fair ...	2
There is little interaction	1
Groups are in conflict	0

Numerical scores were equally weighted and summarized for each of the 20 criteria in the sustainability model, yielding a maximum possible score of 80. Results were summarized in spreadsheet format then imported into Statview, a statistical analysis program.

Results

Twenty-five cities returned completed surveys, a response rate of 56% (Table 2). The geographic distribution of responding cities ranged across the continental United States. City population ranged from 41,643 (Rock Hill, South Carolina) to 3,719,000 (Chicago, Illinois). The average population was 431,187 (median population was 269,063). The size of respondent cities ranged from 4,403 to 122,248 ha (17.0 to 472 mi^2) with an average area of 27,454 hectares (106 mi^2).

Table 2. Population and size of responding cities.

City	Population (1990)	Area (ha)
Livermore, CA	56,741	5,076
Modesto, CA	180,000	8,761
San Francisco, CA	700,000	12,691
Colorado Springs, CO	281,140	35,224
Denver, CO	467,610	40,049
Atlanta, GA	415,200	34,188
Chicago, IL	3,719,000	59,173
Fort Wayne, IN	180,000	—
Topeka, KS	119,883	14,426
Louisville, KY	269,063	15,540
Baton Rouge, LA	380,105	122,248
Lowell, MA	104,000	—
Baltimore, MD	750,000	22,533
Cincinnati, OH	365,000	19,425
Cleveland, OH	505,616	19,943
Providence, RI	160,000	—
Charleston, SC	80,414	11,370
Rock Hill, SC	41,643	6,195
Sioux Falls, SD	100,814	11,655
Ft. Worth, TX	447,619	76,455
Mesquite, TX	101,484	10,878
Salt Lake City, UT	160,000	27,972
Seattle, WA	516,259	23,828
Milwaukee, WI	628,088	24,812
Cheyenne, WY	50,008	4,403

Although the surveys were addressed to the individual mayors in each city, for the most part they were completed by professional staff members within city government. Job titles included urban forester, city forester, city arborist, park superintendent, landscape supervisor, natural resource manager, and director of landscape and forestry. In two cases (Chicago, Illinois, and Lowell, Massachusetts), surveys were completed by program directors (Chicago: Greenstreets; Lowell: Parks and Conservation Trust). For some cities, more than one person took part in completing the survey.

The average score for the respondent cities was 48.8, with a range from 27 to 61 (maximum possible score of 80) (Figure 1; Table 3 and Table

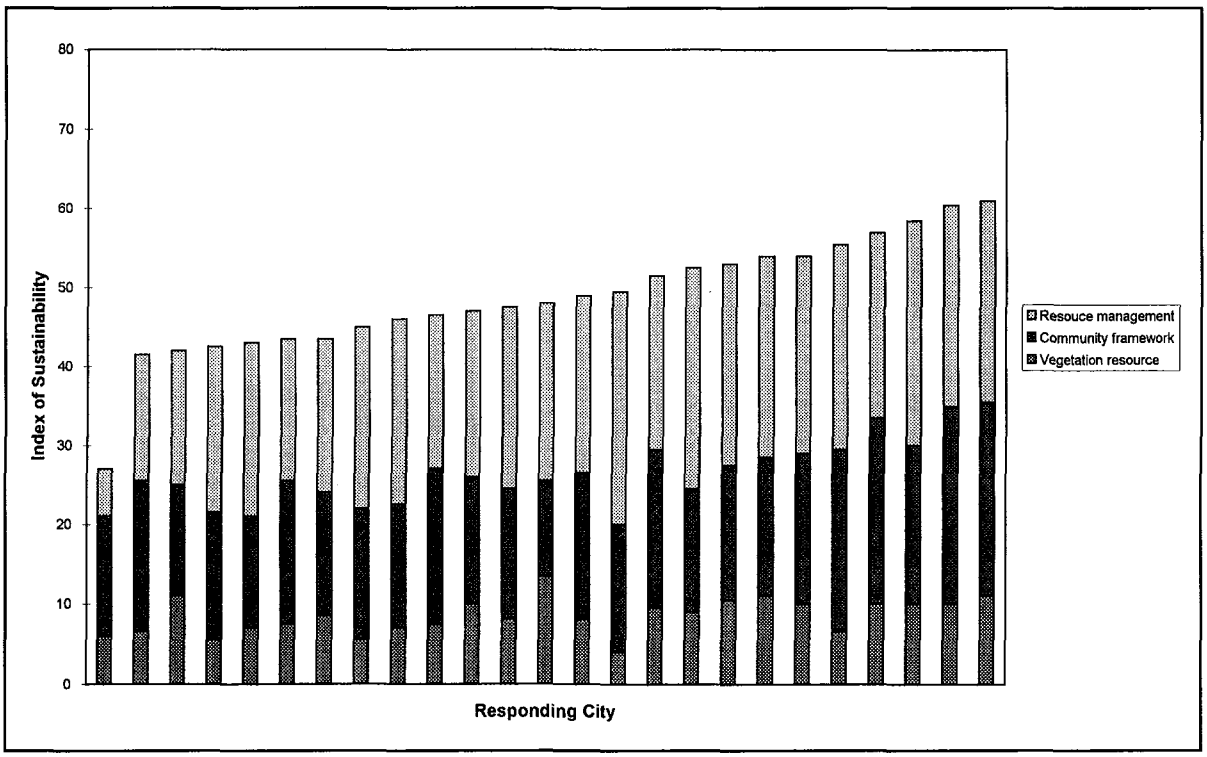

Figure 1. Compiled urban forest sustainability model scores of responding cities.

4). A wide range in scores existed among the three components of the sustainability model. For the vegetation resource component, the average value was 8, with a range of 4 to 13.5 (maximum possible score: 16). For the community framework component, the average score was 17.9, with a range of 12 to 25 (maximum score: 28). The range in scores for the resource management component was 6 to 29, with an average of 22.4 (maximum score: 36). No significant relationship was found between overall score and city population or size. Both high and low scores were obtained by large and small cities.

The average numerical score for all 20 criteria in the sustainability model for all respondent cities was 2.43 (SE_{mean} 0.04). The range in scores was 1.78 to 3.06 (maximum score: 4) (Figure 2; Table 5). The two lowest-scoring criteria were both in the Community Framework component. One dealt with the involvement of holders of large private and institutional lands in management of the urban forest, with a score of 1.78. Only 13 cities had information about this constituent group. The second low-scoring question involved regional cooperation among communities, with a score of 1.98.

The highest-scoring criteria were also in the Community Framework component. The criterion dealing with community awareness of trees and urban forests had an average score of 3.06. Other high-scoring criteria were neighborhood action in urban forest planning and management (2.96), cooperation among green industry groups (2.88), capacity of city staff to implement a citywide management plan (2.88), and the use of tree care standards as a management tool (2.86).

Responses to the open-ended questions reflected the views of municipal urban forestry/arboriculture staff on a variety of topics. For example, several questions considered the role of constituent groups in urban forest management (Table 6 and Table 7). Staff completing the surveys viewed city government and community groups as the most important constituent groups (Table 6). In contrast, business districts, corporations, and private landholders were seen as less important and not critical. In two cases, respon-

dents viewed city government and the general public as a liability to urban forest management.

Respondents to the survey also commented on the importance that various city departments place on the urban forest (Table 7). The most positive comments were made about forestry and parks units. In contrast, 20% to 25% of the respondents viewed the public utility and public works units in a negative way (e.g., "These departments view trees and urban forests as a liability").

Community groups were considered either important or vital to the management of public trees (Table 8). None of the responding cities regarded community groups in a negative manner. Contributions made by such groups included general awareness of the need for management, a source of direct labor, and financial support. Issues to which community groups responded in a positive manner included tree planting and the environmental benefits provided by trees. Issues evoking negative attitudes included uplifted sidewalks, litter, and interference with signs and lights.

Respondents provided detailed information about their city's urban forest resource. Sixty percent of respondents knew the number of trees on streets; 20% knew the number of park trees. However, only one respondent knew the number of trees in the entire city (public and private land). Sixty-four percent of respondents knew the extent of canopy cover across their community and 40% had specific target goals for the amount of cover.

For cities with urban forest management plans (64% of respondents), such plans were largely restricted to public trees. Only one city (Sioux Falls, South Dakota) had an urban forest management plan that considered all trees in the community, both public and private.

Existing urban forest management included use of a number of tools for assessing tree species, age, condition, and location (Table 9). Resource information was incorporated into geographic information systems (GIS) in 40% of surveyed communities. Other assessment tools cited by respondents included inventories, aerial photographs, and windshield surveys. Use of comprehensive assessment tools was clearly reflected in the scores for the Vegetation Resource category. Communities that were aware of the species mix had knowledge of the age distribution as well.

Table 3. Summary of survey results for the model of urban forest sustainability.

Component	Maximum score	Range low	Range high	Average
Vegetation Resource	16	4	13.5	8.5
Community Framework	28	12	25	17.9
Resource Management	36	6	29	22.4
Overall	**80**	**27**	**61**	**48.8**

Table 4. Urban forest sustainability model scores for responding cities.

City No.	Score Veg. Res.	Comm. Frame.	Res. Mgt.	Total
1	6	15	6	27
2	6.5	19	16	41.5
3	11	14	17	42
4	5.5	16	21	42.5
5	7	14	22	43
6	7.5	18	18	43.5
7	8.5	15.5	19.5	43.5
8	5.5	16.5	23	45
9	7	15.5	23.5	46
10	7.5	19.5	19.5	46.5
11	10	16	21	47
12	8	16.5	23	47.5
13	13.5	12	22.5	48
14	8	18.5	22.5	49
15	4	16	29.5	49.5
16	9.5	20	22	51.5
17	9	15.5	28	52.5
18	10.5	17	25.5	53
19	11	17.5	25.5	54
20	10	19	25	54
21	6.5	23	26	55.5
22	10	23.5	23.5	57
23	10	20	28.5	58.5
24	10	25	25.5	60.5
25	11	24.5	25.5	61

Discussion

The survey was designed to evaluate the utility of the model developed by Clark et al. (1997) in assessing the sustainability of urban forests. To that end, the survey asked both closed- and open ended questions about each criterion and per-

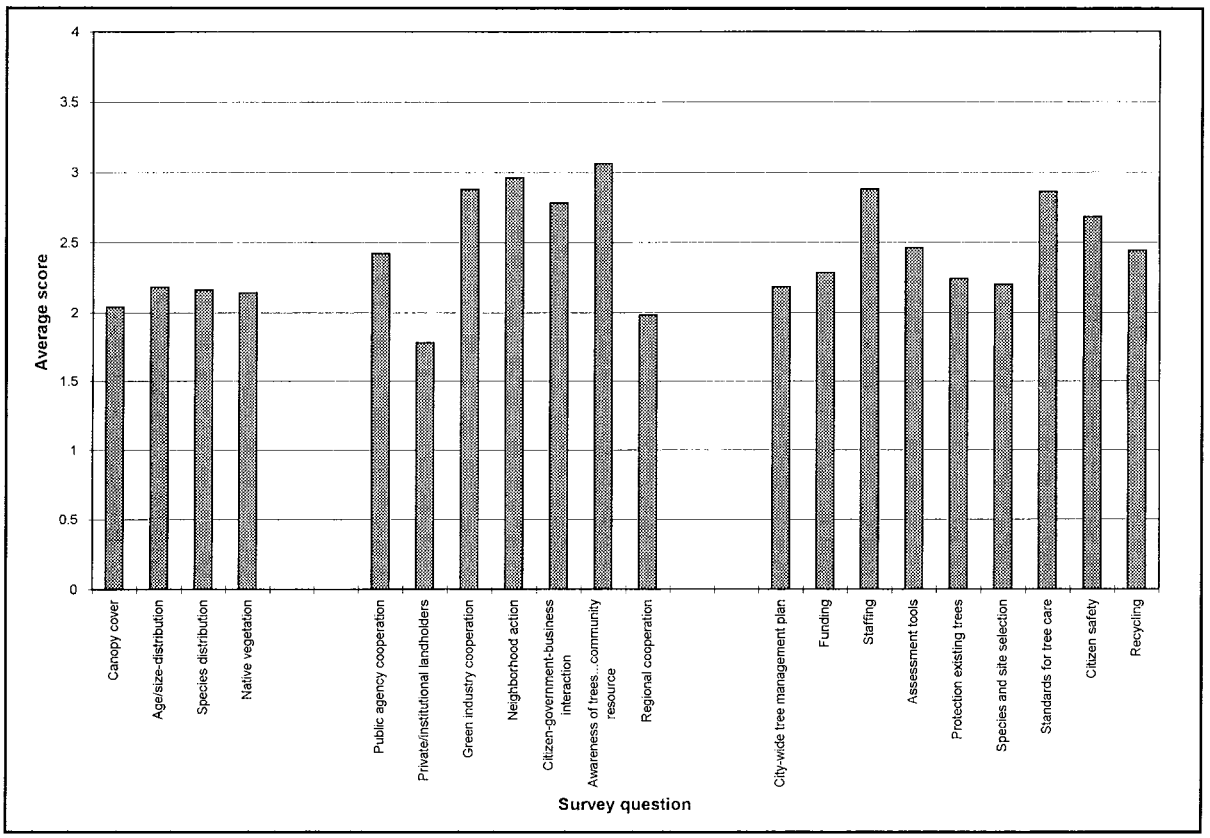

Figure 2. Compiled scores to urban forest sustainability model survey questions.

formance indicator contained in the model. By assigning a numerical rating to each performance indicator, researchers could compute for each city a summary score associated with progress towards a sustainable urban forest. In this way, a quantitative assessment of sustainability could be developed.

Under the model developed by Clark et al., a score of 80 represents a sustainable urban forest. Among the responding cities, the average score was 48.8, with a range from 27 to 61 (Table 4 and Figure 1). The model divides 20 criteria into three categories. The average score (as a percentage of the maximum) for each of these components was Vegetation Resource, 53%; Community Framework, 64%; and Resource Management, 62%

Results for each city among the three categories were not uniform. There was wide variation among components—communities with high scores in one of the components did not necessarily have high scores in the others. For example, the community with the lowest score (4 of a possible 16) in the Vegetation Resource component had the highest score (29 of 36) in the Resource Management component.

Scores obtained from this survey reflect two of the important concepts of the sustainability model: 1) sustainable urban forests require human intervention and 2) trees growing on private lands comprise the majority of urban forests (Clark et al. 1997). For the first concept, the model includes the active interaction and participation of government, businesses, citizens, and other constituent groups. Because urban forests are a mix of naturally occurring and planted trees in specific locations, their creation and preservation require active planning and management by a diverse group of owners, managers, and stakeholders.

Integrating management of private forests and lands into a citywide plan is a significant challenge to communities. For many of the model's performance indicators, the difference between a score of 2 and 3 is based upon consideration of trees on private lands. Unfortunately, few cities are aware of management efforts on private lands, let alone actively interact with those managers. A broadening of focus to consider all trees in the city must occur in order to achieve substantial progress towards sustainability. More actively involving private landholders in cooperative management programs and goals requires new thinking and approaches other than those historically employed with individual citizens. This does not mean that public agencies should oversee, direct, or otherwise regulate management of trees on private lands. Rather, there is a need for shared vision and agreement on goals, objectives, and management approaches.

Another aspect of broadening the focus is regional cooperation in urban forest management. Most of the respondents noted their involvement in such professional organizations as the International Society of Arboriculture as examples of such cooperation. The model, however, considers regional cooperation to be the positive interaction of neighboring communities in urban forest management. This could take the form of consistency in tree preservation and resource conservation policies, pest management programs, or storm water runoff. The recently completed Chicago Urban Forest Ecosystem Project (McPherson et al. 1994) and Sacramento Urban Forest Ecosystem Study are examples of the potential to develop and implement regionally based resource assessment and management programs. Another example of the potential for regional cooperation involves the integration of riparian forests into urban storm drainage systems (Ellis 1995).

When we evaluated the survey results, several limitations of the sustainability model and survey approach became clear. First and foremost, the sustainability score represents the views of the respondent (i.e., the person completing the survey) resulting in a strong bias on at least two levels. The first bias of the respondent involves his or her perceptions and attitudes about the sustainability model. While we might hope that the municipal arborist or urban forester who completed these surveys represented the broader community views about a topic, there is no way to ensure this fact. The second respondent bias involves the cities and their elected officials. Surveys were sent to the mayor of each community, who then transferred it to the respondent. That this transfer occurred represents a positive interest in the urban forest.

Table 5. Scores for urban forest sustainability model criteria.

Model components and criteria	Mean	Standard error
Vegetation Resource		
Canopy cover	2.04	0.18
Age/size distribution	2.18	0.16
Species distribution	2.16	0.14
Native vegetation	2.14	0.19
Community Framework		
Public agency cooperation	2.42	0.12
Private/institutional landholders	1.78	0.20
Green industry cooperation	2.88	0.13
Neighborhood action	2.96	0.14
Citizen-government-business interaction	2.78	0.16
Awareness of trees as a community resource	3.06	0.18
Regional cooperation	1.98	0.14
Resource Management		
Citywide tree management plan	2.18	0.15
Funding	2.28	0.19
Staffing	2.88	0.16
Assessment tools	2.46	0.15
Protection existing trees	2.24	0.19
Species and site selection	2.20	0.16
Standards for tree care	2.86	0.16
Citizen safety	2.68	0.21
Recycling	2.44	0.19

Table 6. Constituent groups important to urban forest sustainability.

	Importance of constituent groups to urban forest			
Group	Absolutely vital	Important	Nice but not critical	No. of responses
City government	18	6	1	25
Community groups	12	9	3	24
Public	9	12	1	22
Green industry	5	14	3	22
Business districts	3	7	12	22
Corporations	1	10	11	22
Private landholders	2	8	10	20

Another limitation of the survey involves privately owned trees. The sustainability model considers *all* trees within a community. The more information a city possesses about all trees in its communities, the higher its score. In some cases, the survey was completed by a team of staff members from such departments as parks, streets, and forestry. Scores from these communities are likely to be higher than those from cities for which the survey was completed by a single staff member whose responsibility involved only parks or only streets.

Finally, several of the model's criteria involve preservation of existing trees, particularly in native forests. Although it was not intentional, cities without a native forest resource were undoubtedly penalized in their overall score. We minimized this penalty by averaging scores for other criteria within the component group and applying the average to the questions dealing with a native forest resource.

We caution that the results obtained from this survey are not representative of the municipal urban forestry programs nationwide, for several reasons. First, we did not sample communities at random. Rather, we included cities about which we had prior knowledge of their urban forestry program or government structure. On this basis, the participant cities would be expected to score higher than those from a randomly selected group. Second, respondents to the survey represent a positive self selection (i.e., only communities with positive feelings about urban forests took the time to complete the survey). This includes both urban forestry professionals and elected officials. For cities that responded to the survey, the mayor felt strongly enough about the issue to pass the request on to the appropriate staff.

While we believe the sustainability model can be a powerful tool to communities in assessing sustainability, results of the survey identified some limitations. For example, the model's criteria are equally weighted. Given the central importance of the tree resource in making an urban forest, this component area may warrant stronger weighting. We also recognize that a long, complicated survey is not the most efficient method of assessment and are investigating more concise, well-structured evaluation forms.

Table 7. Attitudes of city departments about the urban forest (as perceived by the respondents).

	Attitude about the urban forest			
Department	Excellent[a]	Fair[b]	Poor[c]	Responses
Public utility	6	14	5	25
Parks	17	7	—	24
School district	6	17	1	24
Forestry	22	—	—	22
Planning	14	8	—	22
Boards and commissions[d]	14	7	—	21
Public works	5	11	5	21
Public housing	4	9	—	13
Assessment districts	6	4	—	10

[a]Trees are great
[b]Neutral
[c]Trees are liability
[d]E.g., design review, tree board

Table 8. Involvement of community groups in management of urban forests.

Topic	No. of responses
Importance of community groups to management of public trees	
Critical	8
Important	10
Neutral	5
Negative	0
Contributions of community groups to urban forest	
Direct financial support	6
Indirect financial support	7
Direct labor	11
General awareness	15
*Issues associated with **positive** citizen attitudes*	
Support/demand tree planting	5
Environmental benefits (including energy conservation)	5
General support	3
Neighborhood improvement	3
Articles/editorials in newspaper	2
Increased property values	2
Dislike large-scale removal	2
Other	7
*Issues associated with **negative** citizen attitudes*	
Uplifted sidewalks	7
Litter (leaves, fruit); demand removal, prevent planting	6
Interfere with signs and lights	4
Homeowner responsibility for care	2
View pruning	2
Vandalism	2
Other	7

Table 9. Urban forest assessment tools used by responding cities.

	Resource type			
	Public trees			Private
Assessment tool	*street*	*park*	*other*	*trees*
Geographic information system	10	10	1	3
Complete inventory	9	6	—	—
Partial inventory	11	11	—	1
Mapping from aerial photographs	11	12	2	6
Other (e.g., windshield survey)	10	7	—	2

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