A MODEL OF URBAN FOREST SUSTAINABILITY

by James R. Clark, Nelda P. Matheny, Genni Cross and Victoria Wake

Abstract. We present a model for the development of sustainable urban forests. The model applies general principles of sustainability to urban trees and forests. The central tenet of the model is that sustainable urban forests require a healthy tree and forest resource, community-wide support and a comprehensive management approach. For each of these components, we present criteria and indicators for assessing their status at a given point in time. The most significant outcome of a sustainable urban forest is to maintain a maximum level of net environmental, ecological, social, and economic benefits over time.

Creation and management of urban forests to achieve sustainability is the long-term goal of urban foresters. The notion of sustainability in urban forests is poorly defined in both scope and application. Indeed, the question of how to define sustainability, and even whether it can be defined, is an open one (9, 12). At a simple level, "a sustainable system is one which survives or persists" (5). In the context of urban forests, such a system would have continuity over time in a way that provides maximum benefits from the functioning of that forest.

Since there is no defined end point for sustainability, we assess sustainability by looking backwards, in a comparative manner (5). In urban forests, we measure the number of trees removed against those replanted or regenerated naturally. In so doing, we assess progress towards a system that "survives or persists." Therefore, our ideas of sustainability are "really predictions about the future or about systems . . . (5)."

This paper presents a working model of sustainability for urban forests. We describe specific criteria that can be used to evaluate sustainability, as well as measurable indicators that allow assessment of those criteria. In so doing, we accept sustainability as a process rather than a goal. As suggested by Kaufmann and Cleveland (12) and Goodland (5), we consider social and economic factors as well as natural science. Goodland believed that "general sustainability will come to be based on all three aspects" (social, economic and environmental). Maser (14) described sustainability as the "overlap between what is ecologically possible and what is societally desired by the current generation", recognizing that both will change over time.

Therefore, our approach integrates the resource (forests and their component trees) with the people who benefit from them. In so doing, we acknowledge the complexity of both the resource itself and the management programs that influence it. We also recognize that communities will vary in both the ecological possibilities and societal desires.

Defining Sustainability

In developing a model of sustainable urban forests, we first examined how other sustainable systems were defined and described. Although we have concentrated on forest systems, other examples were considered. While some principles of sustainable systems were directly applicable to urban forests, others require modification or were in conflict with the nature of urban forests and forestry.

The Brundtland Commission Report (21) has generally served as the starting point for discussion about sustainable systems. It defined sustainable forestry as:

"Sustainable forestry means managing our forests to meet the needs of the present without compromising the ability of future generations to meet their own needs by practicing a land stewardship ethic which integrates the growing, nurturing and harvesting of trees for useful products with the conservation of soil, air, and water quality, and wildlife and fish habitat."

Both Webster (22) and Wiersum (23) examined this definition from the perspective of forest management. They recognized that issues of *what* is to be sustained and *how* sustainability is to be implemented are unresolved. Wiersum (23)

acknowledged the historical focus on sustaining yield and its recent broadening to sustainable management. Webster (22) suggested a need for focus on the issue of *scale:* the size of the area or space to be included.

Further refinements in the Brundtland Commission's definition of sustainability were made by Salwasser (16) and Sample (17). Salwasser (16) described sustainability as:

"Sustainability means the ability to produce and/or maintain a desired set of conditions or things for some time into the future, not necessarily forever."

Salwasser (16) included environmental, economic and community based components, acknowledging that sustainability is not simply a resource matter. He also stressed that the goals and objectives for forest management cannot exceed the biological capacity of the resource, now and into the future.

Sample (17) focused more closely on forest management, emphasizing the need for shared vision among diverse property owners. In a workshop on ecosystem management, Sample described sustainable forestry as:

"Management and practices which are simultaneously environmentally sound, economically viable and socially responsible."

Some definitions of sustainable forests are not directly applicable to urban settings. For example, the description presented at the conference on Sustainable Forestry (18) included comments about capacity for self-renewal. Since regeneration of urban forests must occur in a directed, location-specific manner, use of such a definition is inappropriate.

Other definitions consider the goal of sustainable forests in a manner inconsistent with our concept of urban forests. Thompson *et al.* (20) described sustainability as "programs that yield desired environmental and economic benefits without wasteful, inefficient design and practices." While these authors were interested in urban settings, their approach was limited to municipal forestry programs rather than city-wide processes or results. Dehgi *et al.* (6) focused on California's native Monterey pine forest and restricted their definition of sustainability to that system. Moreover, their interest was limited to sustaining the "natural dynamic genetic process." In another approach, the American Forest and Paper Association's Sustainable Forestry Initiative (1) is largely aimed at industrial forest practice and products. This focus on industrial forestry seems largely incompatible with urban environments.

Given the examples noted above, the role of humans in sustainable systems (including forests) is generally accepted. However, Botkin and Talbot (2) (as criticized by Webster) argued that sustainable development of tropical forests requires non-disturbance by humans. Again, this idea is incompatible with urban forests.

Applying Concepts of Sustainable Forests to Urban Forests

In moving the concepts of sustainable development of forests towards implementation and practice, Webster (22) raised several significant questions. We have considered these questions from the urban forest perspective:

What objects, conditions, and values are to be sustained?

In urban areas, we focus on sustaining net benefits of trees and forests at the broadest level. We are sustaining environmental quality, resource conservation, economic development, psychological health, wildlife habitat, and social well-being.

What is the range of forest activities that contribute to sustainable development?

Simply put, urban forests require a broad set of activities, from management of both single trees and large stands to education of the community about urban forests and development of comprehensive management plans.

What is the geographic scale at which sustainable development can be most usefully applied?

Political borders do not respect biology (and vice versa). Principles of ecosystem management argue for a scale based on ecological boundaries such as watersheds. However, cities form discrete political, economic and social units. We must respect the reality that political borders may be more significant to management than ecological boundaries. Urban forestry programs work within

this geographical framework.

For this project and model, we have chosen to focus on the city and its geographic limits. While this approach may violate some of the biological realities of forest stands, it logically reflects the jurisdictional boundaries and typical management units found in cities. The more common alternative approach, working with ecosystems, is not without problems of definition and scale (7).

What is the relationship of sustainable development for (urban forests) to new technology, effectively applied research and investment in forest management?

Urban forests stand to benefit tremendously from new technology, information and investment. Not only will the ability to select and grow trees in cities be enhanced, but the ability to quantify the benefits accrued by their presence will expand.

Wiersum (23) provided an in-depth look at sustainability in forest systems, noting the long history of the concept in forest practice. Many would argue that the concept of sustained yield is not equivalent to sustainable development. Gatto (9) discusses this fact at length. However, Wiersum (23) observed the evolution of forest sustainability towards multiple use, biological diversity, mitigating climate change and socioeconomic dimensions. Wiersum summarized four concepts involved with sustainable forest management as maintenance or sustenance of:

- forest ecological characteristics
- yields of useful forest products and services for human benefit
- human institutions that are forest-dependent
- human institutions that ensure forests are protected against negative external institutions.

A similar perspective on sustainable forest management (13) described the measurable criteria as:

- desired future condition (the vision of the forest in the future)
- sustained yield
- ecosystem maintenance
- community (city) stability

Keene (13) also noted that these principles can be practiced in traditional forest management. Products derived from forests in which sustainable forest management is practiced may receive a third-party certification as such, in a manner similar to certification of organically-grown produce.

Maser, (14), Wiersum (23) and Charles (4) all argued that a sustainable forest would include biological, social and economic issues. For example, from the perspective of a fishery resource, sustainability is the simultaneous pursuit of ecological, socioeconomic, community and institutional goals (4). In Maser's view of ecological sustainability, the goals and needs of society must reflect the potential of the resource to meet them. This idea may be universal for sustainable development and must certainly be for urban forests.

This approach can be directly applied to cities, for we want urban forests to contribute to environmental, economic and social well-being. We need not sacrifice one goal in pursuit of another. Trees reduce atmospheric contaminants at the same time that they enhance community well-being. While there may be conflicts in specific situations (eg. planting trees under utility lines or using invasive species), in general, all of the broad goals for urban forest sustainability are compatible with the others. In this sense, when we focus on appropriate management of trees and urban forests, where management activities take place with community-supported goals and objectives, we focus on sustaining a broad range of values.

We also concur with Charles' (4) conclusion that sustainability can only be achieved when:

- Control is local (for fisheries, community and region-wide)
- Management is adaptive, recognizing the dynamic resource and its complexity
- Property rights are respected

In summary, a wide range of definitions for sustainable development have been derived from the original concept of the Brundtland Commission. No universally accepted derivation has arisen for forestry. Despite this problem, progress has been made in identifying criteria and markers for success.

Characteristics of Urban Forest Sustainability

Given the general characteristics of sustainable systems and the specific nature of urban forests, we identified 4 principles to which any model of sustainability must adhere.

1. Sustainability is a broad, general goal. While we may be able to describe the desired functions of a sustainable urban forest, we cannot yet design the forest to optimize them. Although we know that urban forests act to reduce atmospheric contaminants, we do not yet know how to design those forests to maximize that function. However, we accept that existing urban forests provide these functions to some degree. Trees in cities serve to improve community well-being, reduce the urban heat island, eliminate contaminants from the atmosphere, etc. While there are costs involved in planting, maintaining and removing trees in cities, in a sustainable urban forest the net benefits provided by these functions are greater than the costs associated with caring for the forest. A sustainable urban forest provides continuity of these net benefits over time and through space. We therefore have decided to recognize the general character of sustainable systems and develop steps that form such a system in urban areas.

2. Urban forests primarily provide services rather than goods. Descriptions of sustainable systems usually focus on the goods that system provides, i.e. sustained yield. Forests provide fuel and fiber, agronomic systems provide food and fiber, fisheries provide food, etc. In such examples, goods are the primary output.

In contrast, goods comprise a rather limited output of the urban forests. The most important outputs are services, such as reducing environmental contamination (from removing atmospheric gases to moderating storm water runoff), improving water quality, reducing energy consumption, providing social and psychological well-being, providing for wildlife habitat, etc. These services, or benefits, are provided in two ways: 1) direct (shading an individual home, raising the value of a residential property) and 2) indirect (enhancing the well-being of community residents).

In planting and maintaining sustainable urban forests, we should strive for a balance among all benefits and not maximize the output of one service at the expense of all others. For example, one of the benefits that urban forests provide is wildlife habitat. Maintaining the largest wildlife habitat possible could conflict with other services, such as limiting economic development from property development or creating conflicts with humans.

3. Sustainable urban forests require human intervention. One of the wonderful characteristics of natural systems is their capacity for self-maintenance. Sustainable forests, farms and fisheries take advantage of this fact by harvesting some limited segment of the resource, often with a period of rest to allow renewal and replacement. The Brundtland Commission Report (21), Maser (14) and Charles (4) emphasized this critical aspect of the resource to be sustained. For example, Goodland (10) defined environmental sustainability as "maintenance of natural capital." Maser noted that a biologically sustainable forest is the foundation for all other aspects of a sustainable system. In forestry, there can be no sustainable yield, sustainable industry, sustainable community or sustainable society without a biologically sustainable resource. As Charles put it (for fisheries), "If the resource goes extinct, nothing else matters."

Many (but not all) urban forests are a mosaic of native forest remnants and planted trees. The native remnants may have some capacity for self-renewal and maintenance, particularly in greenbelts and other intact stands. However, the planted trees have essentially no ability to regenerate *in place*. Therefore, we must accept, acknowledge and act on the fact that urban forests (particularly in the United States) may have a limited ability to retain or replace biological capital (to use Maser's term). This is particularly the case when we desire that regeneration occur in a manner appropriate for human benefits. Indeed, unwanted tree reproduction may actually have a net cost for control and eradication programs.

Sustainable urban forests cannot be separated from the activities of humans. Such activity can be both positive and negative. In the latter case, creation and maintenance of urban infrastructure

can be extremely destructive and disruptive. In essence, we superimpose cities atop forests. The greater the imposition, the less natural the forests appear and function (D. Nowak, personal communication).

The adverse impacts of humans can be mitigated by positive actions such as planning, planting, and management; all occurring with common commitment and shared vision. We cannot separate sustainable urban forests from the people who live in and around them. In fact, we want to meld the two as much as possible.

The implications of this principle are far-reaching. First, urban forests require active, consistent, continuing management. The accrual of net benefits can only occur when adequate and reasonable care is provided. Second, tree managers (both public and private) must involve the surrounding community in decisions and actions regarding urban forests. We do not suggest abdicating responsibility on the part of tree managers; we advocate sharing it.

4. Trees growing on private lands compose the majority of urban forests. While publicly - owned trees (primarily in parks and along streets and other rights-of-way) have been the long-standing focus of urban forestry, they comprise only a portion of the urban forest. An estimated 60 - 90% of the trees in urban forests in the United States are found on privately owned land (see 19; also G. McPherson, pers. communication). Therefore, sustainable urban forests depend to a large degree on sustainable private forests.

If we consider further that trees probably are not evenly distributed among all private land-holders, then we may also conclude that a small number of land owners and managers may be responsible for a large fraction of urban trees. For example, universities, business parks, corporate campuses, commercial real estate, autonomous semi-public agencies, utilities, etc. may manage large numbers of trees. The success of any effort at sustainability must include their participation and commitment.

However, small private landholdings, particularly residential properties, may also constitute a significant fraction of community trees. Their contribution to the urban forest must be considered in any effort towards sustainability.

Defining Sustainable Urban Forests. Applying these 4 principles leads to the following definition of a sustainable urban forest:

"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."

Applying this definition in urban areas requires accepting 3 ideas:

1. Communities must acknowledge that city trees provide a wide range of net benefits. Planting, preserving and maintaining trees is neither simply a good thing nor an exercise. Rather, urban forests are essential to the current and future health of cities and their inhabitants.

2. Given the goal of maintaining net benefits over time, the regeneration of urban forests requires intervention and management by humans. To quote David Nowak, "people want and need to direct the renewal process because natural regeneration does not meet most urban needs." Therefore, urban forests cannot be sustained by nature, but by people.

3. Sustainable urban forests exist within defined geographic and political boundaries: those of cities. Moreover, sustainable urban forests are composed of all trees in the community, regardless of ownership.

A Model of Urban Forest Sustainability

Given the 3 premises listed above, we developed a model of urban forest sustainability which is founded on three components: 1) vegetation resource, 2) a strong community framework and 3) appropriate management of the resource. Within each component are a number of specific criteria for sustainability (see Tables 1, 2 and 3).

1. Vegetation resource. The vegetation resource is the engine that drives urban forests. Its composition, extent, distribution, and health define the limit of benefits provided and costs accrued. As dynamic organisms, urban forests (and the trees that form them) change over time as they grow, mature and die. Therefore, sustainable urban forests must possess a mix of

Table 1. Criteria of urban forest sustainability for the Vegetation Resource.

Canopy cover	Achieve climate-appropriate tree cover, community-wide.	Though the ideal amount of canopy cover will vary by climate and region (and perhaps by location within the community, there is an optimal degree of cover for every city.
Age distribution	Provide for uneven age distribution.	A mix of young and mature trees is essential if canopy cover is to remain relatively constant over time. To insure sustainability, an on-going planting program should go hand in hand with the removal of senescent trees. Some level of tree inventory will make monitoring for this indicator easier. Small privately owned properties pose the biggest challenge for inclusion in a broad monitoring program.
Species mix	Provide for species diversity.	Species diversity is an important element in the long-term health of urban forests. Experience with species-specific pests has shown the folly of depending upon one species. Unusual weather patterns and pests may take a heavy toll in trees in a city. It is often recommended that no more than 10% of a city's tree population consist of one species.
Native vegetation	Preserve and manage regional biodiversity. Maintain the biological integrity of native remnant forests. Maintain wildlife corridors to and from the city.	Where appropriate, preserving native trees in a community adds to the sustainability of the urban forest. Native trees are well-adapted to the climate and support native wildlife. Replanting with nursery stock grown from native stock is an alternative strategy. Planting non-native, invasive species can threaten the ability of native trees to regenerate in greenbelts and other remnant forests. Invasive species may require active control programs.

species, sizes and ages that allows for continuity of benefits while trees are planted and removed (Table 1).

The vegetation resource of a sustainable urban forest is one that provides a continuous high level of net benefits including energy conservation, reduction of atmospheric contaminants, enhanced property values, reduction in storm water run-off,

Table 2. Criteria of urban forest sustainability for the Community Framework.

Public agency cooperation	Insure all city departments operate with common goals and objectives.	Departments such as parks, public works, fire, planning, school districts and (public) utilities should operate with common goals and objectives regarding the city's trees. Achieving this cooperation, requires involvement of the city council and city commissions.
Involvement of large private and institutional landholders	Large private landholders embrace city wide goals and objectives through specific resource management plans.	Private landholders own and manage most of the urban forest. Their interest in, and adherence to, resource management plans is most likely to result from a community-wide understanding and valuing of the urban forest. In all likelihood, their their cooperation and involvement cannot be mandated.
Green industry cooperation	The green industry operates with high professional standards and commits to city-wide goals and objectives.	From commercial growers to garden centers and from landscape contractors to engineering professionals, the green industry has a tremendous impact on the health of a city's urban forest. The commitment of each segment of this industry to high professional standards and their support for city-wide goals and objectives is necessary to ensure appropriate planning and implementation.
Neighborhood Action	At the neighborhood level, citizens understand and participate in urban forest management.	Neighborhoods are the building blocks of cities. They are often the arena where individuals feel their actions can make the biggest difference in their quality of life. Since the many urban trees are on private property (residential or commercial), neighborhood action is a key to urban forest sustainability.
Citizen - government - business interaction	All constituencies in the community interact for the benefit of the urban forest.	Having public agencies, private landholders, the green industry and neighborhood groups all share the same vision of the city's urban forest is a crucial part of sustainability. This condition is not likely to result from legislation. It will only result from a shared understanding of the urban forest's value to the community and commitment to dialogue and cooperation among the stakeholders.

Table 2. Criteria of urban forest sustainability for the Community Framework (continued)

General awareness of trees as a community resource	The general public understands the value of trees to the community.	Fundamental to the sustainability of a city's urban forest is the general public's understanding of the value of its trees. People who value trees elect officials who value trees. In turn, officials who value trees are more likely to require the agencies they oversee to maintain high standards for management and provide adequate funds for implementation.
Regional cooperation	Provide for cooperation and interaction among neighboring communities and regional groups.	Urban forests do not recognize geographic boundaries. Linking city's efforts to those of neighboring communities allows for consideration and action on larger geographic and ecological issues (such as water quality and air quality).

and social well-being.

There are costs associated with the accrual of these benefits. Dead, dying and defective trees may fail and injure citizens or damage property. Some species may pose a health risk from allergenic responses. Others may compete with native vegetation and limit the function of naturally occurring fragments and systems.

2. Community framework. A sustainable urban forest is one in which the all parts of the community share a vision for their forest and act to realize that vision through specific goals and objectives (Table 2). It is based in neighborhoods, public spaces and private lands.

At one level, this requires that a community agree on the benefits of trees and act to maximize them. On another level, this cooperation requires that private landowners acknowledge the key role of their trees to community health. Finally, in an era of reduced government service, cooperation means sharing the financial burden of caring for the urban landscape.

3. Resource management. In many ways, this component is not simply management of the resource but the philosophy of management as well (Table 3). On one hand, specific policy vehicles to protect existing trees, manage species selection, train staff and apply standards of care focus on the tree resource itself. In contrast, acceptance of a comprehensive management plan and funding program by city government and its constituents allows shared vision to develop.

Cities must recognize that management approaches will vary as a function of the resource and its extent. A goal of maintaining native wildlife habitat may best be achieved where there is a strong native forest resource. For some cities, this is simply not attainable. Similarly, management of the urban forest must exist in connection to the larger landscape (such as adjacent forests). For example, maintenance of intact riparian corridors requires the cooperation of the managing agency of the stream.

Achieving Sustainable Urban Forests. A sustainable urban forest is founded upon community cooperation, quality care, continued funding and personal involvement. It is created and maintained through shared vision and cooperation with an ever-present focus on maximizing benefits and minimizing costs. Taken together, they acknowledge the need for shared vision and responsibility, for direct intervention with the resource and for programs of care that are on-going and responsive. The implementation of

Table 3. Criteria of urban forest sustainability for Resource Management.

City-wide management plan	Develop and implement a management plan for trees on public and private property.	A city-wide management plan will add to an urban forest's sustainability by addressing important issues and creating a shared vision for the future of the community's urban forest. Elements may include: species and planting guidelines; performance goals and standards for tree care; requirements for new development (tree preservation and planning); and specifications for managing natural and open space areas.
Funding	Develop and maintain adequate funding to implement a city-wide management plan.	Since urban forests exist on both public and private land, funding must be both public and private. The amount of funding available from both sources is often a reflection of the level of education and awareness within a community for the value of its urban forest.
Staffing	Employ and train adequate staff to implement a city-wide management plan.	An urban forest's sustainability is increased when all city tree staff, utility and commercial tree workers and arborists are adequately trained. Continuing education in addition to initial minimum skills and/or certifications desirable.
Assessment tools	Develop methods to collect information about the urban forest on a routine basis.	Using canopy cover assessment, tree inventories, aerial mapping, geographic information systems and other tools, it is possible to monitor trends in a city's urban forest resource over time.
Protection of existing trees	Conserve existing resources, planted and natural, to ensure maximum function.	Protection of existing trees and replacement of those that are removed is most often accomplished through policy vehicles. Ordinances that specify pruning standards and/or place restrictions on the removal of large or other types of trees on public and private property and during development are examples.
Species and site selection	Provide guidelines and specifications for species use, on a context-defined basis.	Providing good planting sites and appropriate trees to fill them is crucial to sustainability. Allowing adequate space for trees to grow and selecting trees that are compatible with the site will reduce the long- and short-term maintenance requirements and enhance their longevity. Avoiding species known to cause allergenic responses is also important in some areas.

Table 3. Criteria of urban forest sustainability for Resource Management (continued)

Standards for tree care	Adopt and adhere to professional standards for tree care.	Sustainability will be enhanced by adhering to the professional standards such as the Tree Pruning Guidelines (ISA) and ANSI Z133 publications.
Citizen safety	Maximize public safety with respect to trees.	In designing parks and other public spaces, public safety should be a key factor in placement, selection, and management of trees. Regular inspections for potential tree hazards is an important element in the management program.
Recycling	Create a closed system for tree waste.	A sustainable urban forest is one that recycles its products by composting, reusing chips as mulch and/or fuel and using wood products as firewood and lumber.

Table 4. Criteria and performance indicators for the Vegetation Resource.

Criteria	Performance indicators				Key Objective
	Low	Moderate	Good	Optimal	
Canopy cover	No assessment	Visual assessment (i.e. photographic)	Sampling of tree cover using aerial photographs.	Information on urban forests included in city-wide geographic information system (GIS).	Achieve climate-appropriate degree of tree cover, community-wide.
Age - distribution of trees in community	No assessment	Street tree inventory (complete or sample)	Public - private sampling	Included in city-wide geographic information system (GIS).	Provide for uneven age distribution.
Species mix	No assessment	Street tree inventory	City-wide assessment of species mix	Included in city-wide geographic information system (GIS).	Provide for species diversity.
Native vegetation	No program of integration	Voluntary use on public projects	Requirements for use of native species on a project-appropriate basis	Preservation of regional biodiversity	Preserve and manage regional biodiversity. Maintain the biological integrity of native remant forests. Maintain wildlife corridors to and from the city.

Table 5. Criteria and performance indicators for the Community Framework.

Criteria	Performance indicators				Key Objective
	Low	Moderate	Good	Optimal	
Public agency cooperation	Conflicting goals among departments	No cooperation	Informal working teams	Formal working teams w/ staff coordination	Insure all city departments operate with common goals and objectives.
Involvement of large private and institutional land holders	Ignorance of issue	Education materials and advice available to land-holders	Clear goals for tree resource by private land-holders; incentives for preservation of private trees	Land-holders develop comprehensive tree management plans (including funding)	Large private landholders embrace city-wide goals and objectives through specific resource management plans.
Green industry cooperation	No cooperation among segments of industry (nursery, contractor, arborist). No adherence to industry standards.	General cooperation among nurseries - contractors - arborists, etc.	Specific cooperative arrangements such as purchase certificates for right tree, right place	Shared vision and goals including the use of professional standards.	The green industry operates with high professional standards and commits to city-wide goals and objectives.
Neighborhood action	No action	Isolated and/or limited no. of active groups	City-wide coverage and interaction	All neighborhoods organized and cooperating	At the neighborhood level, citizens understand and participate in urban forest management.
Citizen - government - business interaction	Conflicting goals among constituencies	No interaction among constituencies	Informal and /or general cooperation	Formal interaction, e.g.. tree board w/ staff coordination	All constituencies in the community interact for the benefit of the urban forest.
General awareness of trees as community resource	Low -- trees as problems; a drain on budgets	Moderate -- trees as important to community	High -- trees acknowledged to provide environmental services	Very high -- trees as vital components of economy and environment	The general public understands the value of trees to the community.
Regional cooperation	Communities operate independently	Communities share similar policy vehicles	Regional planning	Regional planning coordination and/or management plans	Provide for cooperation and interaction among neighboring communities and regional groups.

a model for urban forest sustainability would further redirect the traditional orientation of urban forest management away from municipal trees to the mix of public and private trees.

Achieving sustainability for urban forests involves meeting each of these criteria. To assist in this task, we have described indicators of success for each criteria (Tables 4, 5, and 6). A city that meets the highest level of each indicator for each criteria would have the best tools and resources to achieve sustainability.

Our approach of developing criteria and

Table 6. Criteria and performance indicators for Resource Management.

Criteria	Performance indicators				Key Objective
	Low	Moderate	Good	Optimal	
City-wide management plan	No plan	Existing plan limited in scope and implementation	Government -wide plan, accepted and implemented	Citizen - government - business resource management plan, accepted and implemented	Develop and implement a management plan for trees and forests on public and private property.
City-wide funding	Funding by crisis management	Funding to optimize existing population	Adequate funding to provide for net increase in population and care	Adequate funding, private and public, to sustain maximum potential benefits	Develop and maintain adequate funding to implement a city-wide management plan.
City staffing	No staff	No training	Certified arborists on staff	Professional tree care staff	Employ and train adequate staff to implement city-wide management plan.
Assessment tools	No on-going program of assessment	Partial inventory	Complete inventory	Information on urban forests included in city-wide GIS	Develop methods to collect information about the urban forest on a routine basis.

indicators is patterned after that found in the Santiago Agreement (11) which suggested criteria and indicators for the conservation and sustainability of temperate and boreal forests. It recognized that both quantitative and qualitative (descriptive) indicators were needed, for not all criteria could be accurately measured.

Conclusions

Maser suggested that ecological sustainability encompasses 4 ideals:

1. Providing a long-term balance between society and the resource, today and in the future.
2. Seeking to increase the overlap between societal desires and ecological possibilities.
3. Developing assessment tools for both the resource and its outputs (benefits, services).
4. Restoring ecosystems.

Our model for urban forest sustainability adheres to these 4 ideals, placing them in an urban context. It recognizes the nature of society in cities and encourages participation at the broadest level. The model also acknowledges the need to foster regeneration, to provide for the continuity of the resource. Management of a sustainable urban forest is based upon a shared vision for the resource, in which goals and needs are balanced. Since sustainability is a general goal, we must be able to assess our progress relative to defined standards. Finally, we recognize that our actions, through such activities as development, will damage forests and their function. We accept the responsibility of restoration.

Urban trees and forests are considered integral to the sustainability of cities as a whole (3, 8). Yet, sustainable urban forests are not born, they are made. They do not arise at random, but result from a community-wide commitment to their creation and management.

Obtaining the commitment of a broad community, of numerous constituencies, cannot be dictated or legislated. It must arise out of compromise and respect. While policy vehicles such as ordinances play a role in managing the

Table 6. Criteria and performance indicators for Resource Management (continued)

Protection of existing trees	No policy vehicle or policy not enforced	Tree preservation ordinance present and enforced	Tree preservation plan required for all projects....public, private, commercial, residential	Integrated planning program for conservation and development	Conserve existing resources, planted and natural, to ensure maximum function.
Species and site selection	Arbitrary species prohibitions	No consideration of undesirable species	Identification/prohibition of undesirable species	On-going use of adapted, high-performing species with good site - species match	Provide guidelines and specifications for species use, including a mechanism for evaluating the site.
Standards for tree care	None	Standards for public tree care	Standards for pruning, stock, etc. for all trees	Standards part of community - wide vision	Adopt and adhere to professional standards for tree care.
Citizen safety	Crisis management	Informal inspections	Comprehensive hazard (failure, tripping, etc.) program	Safety part of cost - benefit program	Maximize public safety with respect to trees.
Recycling	Simple disposal (i.e. land filling) of green waste	Green waste recycling	Green and wood waste recycling - reuse	Closed system -- no outside disposal	Create a closed system for tree waste.

urban forest, developing commitment is probably more a function of education, awareness and positive incentives. This may represent our most significant challenge: to provide information that creates commitment and guides action.

This is not to ignore the budgetary requirements for sustainable urban forests. It has long been our belief that if education were adequate, funding would soon follow. Despite the current state of funding, we must hold to this perspective.

Finally, sustainable urban forests also require a viable resource base. While urban foresters and arborists have long felt confident in their ability to sustain the resource, we must acknowledge our limitations as well as our strengths. The optimal structure of urban forests, i.e. the arrangement of trees in a city, remains the subject of research. Our industry must strive to resolve conflicts such as quality of nursery stock, appropriate cultural practices and the match between site considerations and species selection.

Literature Cited

1. American Forest and Paper Association. 1995. Sustainable Forestry Initiative. American Forest and Paper Association. Washington D.C.
2. Botkin, D. and L. Talbot. 1992. Biological diversity and forests. N.P. Sharma (Ed.), pp 47-74. **In** Managing the world's forests: Looking for balance between conservation and development. Kendall/ Hall Publishing Co.
3. Center for the Study of Law and Politics. 1991. Urban Forestry. The Global Cities Project. San Francisco, CA. 112 pp.
4. Charles, A. 1994. *Towards sustainability: The fishery experience.* Ecological Economics 11:201 -211.
5. Costanza, R. and B. Patten. 1995. *Defining and predicting sustainability.* Ecological Economics. 15:193-196.
6. Dehgi, D., T. Huffman and J. Culver. 1994. *California's native Monterey pine populations: Potential for sustainability.* Fremontia 23(1):14-23.

Forestry

7. Fitzsimmons, A. 1996. *Stop the parade.* BioScience 46 (2).
8. Gangloff, D. 1995. *The sustainable city.* American Forests. May/June 30-34, 38.
9. Gatto, M. 1995. *Sustainability: Is it a well-defined concept?* Ecologia (Soc. Italiana di Ecoligia) 16: 235-240.
10. Goodland, R. 1995. *The concept of environmental sustainability.* Annu. Rev. Ecology Systematics 26: 1-24.
11. Journal of Forestry. 1995. *Sustaining the World's Forests — The Santiago Agreement.* Criteria and indicators for the conservation and sustainable management of temperate and boreal forests. Journal of Forestry 93 (4):18-21.
12. Kaufmann, R. and C. Cleveland. 1995. *Measuring sustainability: needed — an interdisciplinary approach to an interdisciplinary concept.* Ecological Economics. 15:109-112.
13. Keene, R. 1995. *A dirt-forester's perspective.* American Forests. May/June 18, 60-61.
14. Maser, C. 1994. Sustainable Forestry — Philosophy, science and economics. St. Lucie Press. Delray Beach, FL. 373 pp.
15. Nowak, D., R. Rowntree, E. McPherson, S. Sisinni, E. Kerkmann and J. Stevens. In preparation. *Urban tree cover analysis.* Submitted to Landscape and Urban Planning.
16. Salwasser, H. 1993. Perspectives on modeling sustainable urban forest ecosystems. D. LeMaster and R. Sedjo (ed.). pp 176-181. **In:** Modeling Sustainable Forest Ecosystems. Forest Policy Center. Washington D.C.
17. Sample, V. A. 1993a. Building partnerships for ecosystem management on forest and range lands in mixed ownerships. Workshop synthesis. Forest Policy Center. American Forests. Washington D.C. 17 pp.
18. Sample, V. A. (editor). 1993b. Defining sustainable forestry: Conference summary. Forest Policy Center. American Forests. Washington D.C. 17 pp.
19. Sampson, N., G. Moll and J. Kielbaso. 1992. Opportunities to increase urban forests and the potential impacts on carbon storage and conservation. R. N. Sampson and D. Hair (ed.). **In:** Forests and Global Change. Volume 1. Opportunities for Increasing Forest Cover. American Forests. Washington D.C.
20. Thompson, R., N. Pillsbury and R. Hanna. 1994. The elements of sustainability in urban forestry. California Department of Forestry and Fire Protection. Riverside, CA. 56 pp.
21. WCED. 1987. Our common future. (The Brundtland Commission Report). Oxford University Press. Oxford England.
22. Webster, H. 1993. *Some thoughts on sustainable development as a concept, and as applied to forests.* Forestry Chron. 69:531-533.
23. Wiersum, K. F. 1995. *200 Years of sustainability in forestry: Lessons from history.* Environmental Management. 19(3):321-329.

Acknowledgments. Thanks to Greg McPherson, Dave Nowak, Richard Rideout, Paul Ries, Ed Macie, and Ray Tretheway for their comments and suggestions. Funding for this project was provided by a grant from the National Urban and Community Forestry Advisory Council through the U.S.D.A. Forest Service Urban and Community Forestry Challenge Cost-share Program (No. G-5-94-20-095).

HortScience, Inc.
P.O. Box 754
Pleasanton, CA 94566

and

California ReLeaf/The Trust for Public Land
3001 Redhill Avenue
Costa Mesa, CA 92626

Zussammenfassung. Das Modell des sich selbsterhaltenden Stadtwaldes wendet allqemeine Prinzipien der Selbsterhaltung auf städtische Bäume und Wälder an. Sich selbst erhaltende Stadtwälder erfordern eine qesunde Herkunft der Pflanzen, kommunale Unterstützung und ein umfassendes Management. Die Kriterien und Indikatoren, um diesen Status zu überprüfen werden hier vorgestellt. Das deutlichste Resultat eines sich selbst erhaltenden Stadtwaldes besteht darin, einen maximalen Grad an umweltbezogenen, ökologischen, sozialen und ökonomischen Vorzügen zu erreichen.