Chapter 26

Managing Urban Ecosystems: A Look to the Future of Urban Forestry

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1. Introduction

Near the end of the 19th century, the American conservation community, led by Gifford Pinchot, was discussing the need for scientific management of forests and related natural resources. The primary concerns at that time were destructive and wasteful timber-harvesting practices and the need for a sustained yield policy (Pinchot, 1947). Urbanization was not an issue. Nineteenth-century cities were very compact in form due to the constraints of transportation and access. It is understandable, therefore, that urban growth was not perceived by Pinchot as a threat to the long-term viability and productivity of forests. Now, in retrospect, as we approach a new millennium, it has become obvious that a century of unparalleled population growth and urbanization has had an extremely detrimental impact on the natural systems and processes that sustain life on this planet. Forests in the heavily populated regions of the Northeast have been decimated and in many places can no longer maintain their functional efficiency in stabilizing soil, purifying water and air, and sustaining biological diversity.

One of the reasons for the demise of forests and associated natural systems is the role that foresters have assumed in urban areas. For most of the 20th-century the urban forestry profession concentrated on the care, management, and replacement of trees in the public rights-of-way and other public property. The emphasis was on the trees themselves with little or no consideration for the role of vegetation, in a broader context, as it contributes to greater societal needs such as clean water and air. Any agency of government did not assume the responsibility for protecting and conserving the functional effectiveness of natural systems in developing areas. Consequently,

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flooding is a recurring problem, storm water infrastructure is inefficient and costly to maintain, summer temperatures in urban areas are higher than in surrounding forested areas by as much as 10°C, energy consumption is excessive, open space is limited, and biological diversity has been significantly reduced.

In looking at the future of urban forestry it is apparent that a new focus must emerge. Restoring the role of forests and related natural resources to the extent possible in existing developed areas and ensuring their proper place in allocating future land use will provide new challenges for the profession in the next century.

1.1. Sustainable Development

1.1.1. Effects of Urban Growth on Natural Systems and Processes

Ignoring natural systems and processes in urban and urbanizing areas can have costly long-term consequences for community sustainability. This has been demonstrated by older cultures in Europe and Asia that have long histories of dealing with the effects of increasing population concentrations on a limited resource base. Centuries of human occupation and intensifying land use in the Netherlands, for example, have reshaped the natural environment there into what has been described as "an almost completely cultural landscape." Ongoing land and resource exploitation is effecting the transfer of genetic information through loss of habitat and species diversity while stressing natural regulatory functions, resulting in excessive air and water pollution (Vos and Zonneveld, 1993). In response, there is a movement in the Netherlands to reintroduce natural areas into the landscape continuum to restore critical ecosystem function (Harms *et al.*, 1993). The Dutch government has prepared a nature policy plan to compensate for the deterioration of natural systems by setting aside 50,000 hectares (123, 550 acres) of land as part of its national physical planning process (Harms *et al.*, 1993). One of the principal strategies to implement the plan is to establish a landscape-level framework that includes a pattern of interconnected zones in which long-term sustainable conditions for nature development and water supply are provided. This system proposes to restore and protect upland groundwater recharge areas in addition to wetlands and riparian zones through reforestation. The process is also expected to restore and enhance biodiversity through the development and dispersal of related plant and animal species (Van Buuren and Kerkstra, 1993).

Fortunately, conditions in the United States have not deteriorated to the extent they have in the Netherlands, since there is 15 times the land area per capita (Vos and Zonneveld, 1993). Signs of environmental stress are beginning to surface in specific locations, however, especially urban areas, owing to the heavy subsidies of energy and materials that must be imported from other ecosystems in order to maintain them (Ecological Society of America, 1995) and the huge quantities of waste products that must be disposed of. The situation is not limited to cities only; environmental issues associated with land use change at the urban–rural fringe are surfacing, as indicated by the New York–New Jersey Highlands regional study (US Department of Agriculture Forest Service, 1992). The Highlands study illustrates the encroachment of urban development into previously rural watersheds, which threatens to degrade the water supply for half of the population of the state of New Jersey.

Chesapeake Bay is one example where human activity has caused a deterioration in water quality resulting in a dramatic decline in aquatic species composition and abundance that has exceeded a threshold level of sustainability (Brush, 1995; US Environmental Protection Agency, 1983). From a reconstructed paleoecological record of indicator organisms and materials preserved in Chesapeake Bay sediments, Brush (1995) concluded that the transformation from a forested to a non-forested landscape was responsible for converting a diverse benthic estuary in the Chesapeake Bay into one dominated by plankton. The benthic resource has high potential for productivity in shallow water systems when light can penetrate the water column. However, accelerated sedimentation and nutrient enrichment caused by changing land use within the surrounding watershed was so intense that it altered the flux of light and energy within the water column, causing a permanent change in aquatic habitat (Brush, 1995; Chesapeake Bay Monitoring Subcommittee, 1989). This situation manifested itself in a significant decline in the relative abundance and quality of various finfish and shellfish. Oyster harvesting, for example, which at one time yielded as much as 15 million bushels annually from the Chesapeake Bay, has been reduced to less than 1% of historical levels (Chesapeake Bay Monitoring Subcommittee, 1989).

Population growth and related land use change, especially over the second half of the 20th-century, have been linked directly to the decline in water quality and the living resources of the Chesapeake Bay (US Environmental Protection Agency, 1983). Nearly six million people live in the Baltimore–Washington–Annapolis metropolitan area, which ranks fourth in the nation behind New York, Los Angeles, and Chicago. Since 1950, total population within the Chesapeake Bay basin has increased more than 60%, from about 8.3 million to 13.6 million (Year 2020 Panel, 1988). This represents an increase in the land consumption rate of from 0.07 to 0.26 ha per person (0.18 to 0.65 acre per person) (Swanson, 1992). Population is expected to reach 16.2 million by the year 2020 which, at the present consumption rate will convert another 687,980 hectares (1.7 million acres) from forests and agriculture to urban use. Most of this growth is expected to occur in counties adjacent to metropolitan areas where 75% to 100% increases are expected. Furthermore, a disproportionate amount of this development is expected to take place within 300 m (1000 fect) of the Bay (Year 2020 Panel, 1988), where maximum impact to natural patterns and processes can be anticipated. The implications of this growth and change are enormous, since this situation is not limited to the Chesapeake Bay. Development patterns are similar all along the Atlantic coastal zone.

1.1.2. Effects of Environmental, Social, and Economic Systems on Urban Decay

Conditions of poverty, social injustice, and environmental contamination in many inner-city areas like Boston, New York, Chicago, Detroit, and Baltimore are testimony to the lack of attention that is being given to the sustainability of urban areas. It is becoming increasingly apparent that all three components of a sustainable ecological system, that is, social stability, economic vitality, and environmental quality, are mutually interdependent like three legs of a stool. If one component is lacking, the system collapses.

For many years, social and economic concerns have driven land use and resource allocation decisions in populated areas, which according to the three-legged stool analogy are not sustainable. As Allen and Hoekstra (1993) have indicated, in order for disturbed ecosystems to function there must be management intervention to substitute the structural integrity that is lacking. This concept seems to be exaggerated in urban environments. For example, little, if any, attention is paid to natural systems in poor neighborhoods where residents (the social component) are concentrating on subsistence issues (the economic component). Therefore, in order to maintain the stability of the system, policy makers, through resource managers, must intervene to support the biophysical component. A clean and well-maintained urban environment is an asset that supports a stable economic base and contributes to stable social systems and institutions.

1.2. Existing Management Responsibilities for Urban Natural Systems

The principle agencies at the federal level that address environmental issues in urban areas are:

- US Forest Service
- US Environmental Protection Agency
- US Fish and Wildlife Service
- Natural Resource Conservation Service

Each agency has programs that provide either financial and technical assistance to states and communities or environmental review of proposed actions or even site-specific remediation. Neither of these agencies, however, has legislative authority to assume natural resource management responsibility on nonfederal land. Nor do state agencies maintain any systematic record of environmental conditions at a specific enough scale that the information can be used to coordinate the efforts of various jurisdictions or individual landowners. Occasionally there is a watershed compact or similar regional entity that reviews individual project proposals in the watershed context. It is rare, however, that regional compacts include multijurisdictional coordination with regard to natural systems and processes. Occasionally, there is a local unit of government where natural resource management is integrated with community services. Unfortunately, these communities are seldom linked to others in the same watershed or ecosystem where collective decisions can be made about natural resource allocations that will assure the sustainability of critical natural systems.

The unfortunate fact is that no agency of government at the federal, state, or local level is responsible for the collective environmental impacts of uncoordinated land and resource allocation decisions in urban areas.

1.3. The Need for a Comprehensive Management Approach

Mitigating the negative effects of urbanization that include excessive loss of liquid water and essential nutrients, soil erosion, and reduction of biological diversity to create sustainable communities will require multiple ecological, social, and economic strategies. Sustainable communities can be described as those that maintain a balance between ecological, social, and economic systems in order to satisfy present needs while protecting the options for future generations to meet their needs as well. One potentially cost-effective strategy that has been overlooked is the aggressive conservation and management of vegetation as a natural element within the built environment.

2. Establishing a Context for Urban Forest Resource Management

2.1. The Urban–Rural Continuum

Urban expansion is primarily a 20th-century phenomenon. Previously, topography and mobility were the major constraints to the growth of cities. Topography was a factor because it required so much more energy to build on steep slopes, and mobility was limited to a distance that people could reasonably travel on foot. By the late 19th century widespread distribution of electricity allowed for the introduction of mass transit systems that extended the city boundary into the urban fringe to create adjacent suburbs. Urban form remained relatively compact around transit stops however, since development was still constrained by a reasonable walking distance (Lazaro, 1979).

It was the automobile that fundamentally changed urban form and blurred the boundary between the city and the surrounding rural lands. Early 20th-century suburbs gradually filled the area between radial mass transit lines while being extended to include a reasonable commuting distance by automobile for the elite at the city's edge (Laurie, 1986). Following World War II, the economic expansion made automobile ownership possible for nearly every working family. Congestion increased; and to meet the need for more efficient movement of traffic as well as improve military mobility, the interstate highway transportation system was initiated. With personal transportation and easy access, workers were liberated from having to live and work in the same location, and the suburban lifestyle became the norm (Lazaro, 1979). A new model is emerging at the end of the 20th-century based on the technological revolution where advanced communication allows workers to live wherever they want.

Rather than providing an escape from the congestion, traffic, and irritation of city living, the suburbs became recognized as an extension of the same urban lifestyle except that the deleterious impact on the land base increased considerably. The Regional Plan Association of New York has estimated that the tristate metropolitan area of New York City, which includes adjacent counties in New Jersey and Connecticut, experienced a 60% increase in urban land use between 1968 and 1990, despite a population growth of only 6% (US Department of Agriculture, Forest Service, 1992). By 1984, 80% of New Jersey's population lived in the suburbs and 84% of the state's labor force was employed there. Corresponding national statistics of 48% and 45%, respectively, indicate that the older more densely populated Northeast has decentralized at a much more rapid rate than the rest of the country (Hamill *et al.*, 1989). Environmental consequences of this urban decentralization include social and economic destruction of inner-city neighborhoods and significant deterioration of water availability and quality in watersheds surrounding metropolitan areas due to the removal of forest cover (Chavooshian *et al.*, 1987; Delleur, 1982). Related problems include the loss of wildlife habitat and functional open space.

2.2. Ecosystem Classification: Natural to Human-Dominated

Urbanization as a process that has substantial environmental implications has been overlooked as a significant source of ecological inquiry according to McDonnell and Pickett (1990). In its recent white paper, *The Scientific Basis for Ecosystem Management*, the Ecological Society of America (1995) essentially ignores urbanization as a long-term sustainability issue. McDonnell and Pickett (1990) have suggested that: "The study of the metropolis as an ecosystem, including its human inhabitants and institutions, would be a radical expansion of ecology" (p. 1232). Furthermore, they propose a framework to help guide the design and integration of a variety of research activities that accounts for the factors that constitute urbanization, that is, the effects of urbanization on the biota and the physical environment and the resultant effects on ecosystems.

The current US Department of Agriculture (USDA) Forest Service process of mapping ecosystems across a range of scales is intended to stratify the earth into progressively smaller areas of land with increasingly uniform ecological potential. It includes eight ecological sub-regions ranging in scale from the domain at the global level down to the land type phase that can be less than 10 acres in size (ECOMAP, 1993). This ecological classification will eventually assist land managers with developing goals and objectives to provide context for sustainable management from the global to the local level that links ecosystem science to natural resource management actions (Ecological Society of America, 1995; Kaufmann *et al*., 1994; ECOMAP, 1993). Unfortunately, unlike European classification systems (Haber, 1990), this process does not account for the change in ecosystem structure and function that has been brought about by intensive human activity.

After many centuries of economic growth and change, European ecologists are more advanced in their consideration of urban structure and function (Vos and Opdam, 1993). Haber (1990) characterizes ecosystems according to decreasing naturalness ranging from bioecosystems, dominated by natural components and biological processes, to technoecosystems, which are totally dependent on human control and external sources of matter and energy. This view of ecological classification is shaped by the European experience where population densities in relation to the United States range from a fourfold increase in Denmark to a 15-fold increase in the Netherlands (Vos and Zonneveld, 1993). Although these countries have substantially higher population densities overall, there are extensive urban concentrations within the United States, particularly along the East and West coasts, with equivalent densities to that of the Netherlands. The State of New Jersey, for example, which is the most densely populated state in the United States, has almost twice as many people per unit area as the Netherlands (New Jersey State Planning Commission, 1992).

The national hierarchical framework of ecological units (ECOMAP, 1993) contains no recognition of anthropogenic factors. This oversight is unfortunate since it ignores the obstacles to long-term sustainability identified by the Ecological Society of America (1995), namely, the adequacy of information on the biological diversity of environments and widespread ignorance of the function and dynamics of ecosystems. Whereas the framework (ECOMAP, 1993) is based solely on biophysical criteria from the domain (global) to the land type phase (site), urban areas are dominated by man-made structures and materials that completely alter ecosystem structure and function.

Various frameworks have been developed for quantifying naturalness that describe the variability of external energy sources required to maintain a system in its present state. For example, a natural forest stand is self-maintaining (Ecological Society of America, 1995), whereas urban–industrial land uses (technoecosystems) have little or no self-maintaining capacity (Haber, 1990). Allen and Hoekstra (1993) advocate a strategy to address ecosystem management in human-dominated systems. It is based on ecological context (which implies self-maintaining capacity) that provides stability and the ability to recover from repeated disturbances. Accordingly, the most effective management will recognize the extent to which the context is missing, identify the resulting lost functional capacity, and subsidize the managed area to the extent possible. By following the hierarchical approach expressed in ECOMAP (1993), the often confusing issue of scale is dealt with systematically (Table 1). The hierarchy accounts for scale at each level from the continent to the site. Ecological units at the various levels in the hierarchy are identified based on associations of biotic and other environmental factors that directly affect or indirectly express moisture, energy, and nutrient inputs that regulate the structure and function of ecosystems. However, because human activity is a major contributing factor that can have a significant effect on ecosystem structure and function, it too needs to be included in the hierarchy. The issue of scale is important here and must be considered when establishing the point where human influences become dominant elements.

Sanders and Rowntree (1983) concluded that the most appropriate framework within which to classify urban vegetation is the standard metropolitan statistical area

Table 1. Ecological Subregions of the United States[a]

Planning and analysis scale	Ecological units	Purpose, objectives, and general use	General size range
Ecoregion			
Global	Domain	Broad applicability for modeling and sampling, strategic planning and assessment	Million to tens of thousands of square miles
Continental	Division		
Regional	Province		
Subregion	Section	Strategic, statewide multi-agency analysis and assessment	Thousands to tens of square miles
	Subsection		
Landscape	Land type assoc.	Multiple community planning and watershed	Thousands to hundreds of acres
Land unit	Land type Land type phase	Management area and project planning and analysis	Hundreds to less than ten acres

[a]Adapted from ECOMAP (1993).

(SMSA), a designation used by the Bureau of the Census. Although the primary objective is to classify vegetation they needed to first identify those areas that can be characterized as urban. The SMSAs account for approximately 20% of the nation's land area. Each SMSA contains at least one central city with a population of no less than 50,000 and includes the economically integrated surrounding counties (Sanders and Rowntree, 1983). These are areas where natural systems and processes are already substantially affected by human activity or they soon will be.

Statewide multiagency analysis and assessment is the stated purpose at the subregional scale in the adjusted national hierarchy (Table 1). Separate guidelines for urban classification and analysis can be prepared at this level that are directed toward ecosystem restoration, management, and long-term sustainability based on existing and projected land use. Land use is an excellent indicator of relative change from natural landscape conditions and used as an indicator of energy, moisture, and nutrient inputs and outputs in urban hydrology and water quality analysis (Lazaro, 1979; Chavooshian *et al.*, 1987).

Within the SMSAs, management emphasis would be on the health, safety, and well-being of the public as opposed to commodity production, which characterizes rural management strategies, all driven, of course, by the fundamental precepts of ecosystem management, which are:

> (1) long-term sustainability as a fundamental value, (2) clear operational goals, (3) sound ecological models and understanding, (4) understanding complexity and connectedness, (5) recognition of the dynamic character of ecosystems, (6) attention to context and scale, (7) acknowledgement of humans as ecosystem components, and (8) commitment to adaptability and accountability (Ecological Society of America, 1995).

2.3. Linking Ecosystem Structure and Function

Structure and function are extremely important concepts when considering an ecological approach to management. In a woodland or rural setting, ecosystem structure begins with the soil that is the foundation for the various layers of the biotic community including mosses, forbs, and grasses, shrubs, subcanopy, and canopy vegetation. Each structural layer is unique in its ability to carry out various functional activities. For example, in processing the energy and matter associated with rainfall, there is a considerable difference between bare soil and a multilayered forest canopy. Rainfall striking bare soil dislodges particles that are carried downslope by sheet flow, which rapidly concentrates into rills and gullies, further eroding the soil due to the concentration of energy and contributing to rapid surface water runoff and downstream flooding.

In contrast, a multilayered forest canopy intercepts the rainfall and distributes its energy throughout the leaves of the canopy as it falls through the boughs to the ground where forest litter facilitates its infiltration into the soil. Infiltrated water is gradually released to the stream channel to maintain stream flow and aquatic life forms. Ecosystem structure in this case significantly alters functional response.

In managing ecosystems' it is important to know the response that is desired and the optimal structure to achieve that response. This is more feasible in rural settings than in urban settings due to the complexity of the urban ecosystem structure, which includes a wide variety of man-made elements including buildings of various sizes and impervious surfaces. Optimal structure to achieve a desired function, such as creation and maintenance of migratory bird habitat, is seldom possible under urban conditions. However, when managing urban ecosystems it is possible to maximize opportunity through vegetation management, given the structural conditions that exist and recognizing that compromise is essential.

2.4. The Multifunctional Role of Vegetation in Urban Environments

Urban forests have historically been managed solely for the purpose of maintaining trees for their own sake and not to achieve any additional societal benefits. This contrasts sharply with the original idea of Pinchot (1947) who defined the concept of conservation, that is the greatest good for the greatest number, that linked forestry to the stewardship of all natural resources. In this age of declining municipal budgets the first programs to be trimmed (no pun intended) are those that have minimal economic value to the community. Trees are pretty and people like them, but in almost every case they will lose out to police, fire, and public works when budgets are tight.

The alternative is to manage forests and related natural resources in populated areas to serve the needs of the people for a clean and healthy environment and demonstrate the ecological, social, and economic benefits that will accrue. Research is currently being conducted that quantifies the value of trees and other vegetation in such areas as carbon sequestration, reducing air and water pollution, heat island mitigation, energy conservation, and storm water management (McPherson *et al.*, 1994; Neville, 1996; see also Chapter 2, this volume). These are issues of value to society that can be addressed in a very cost-effective way by analyzing the functions that the urban forest is to perform and the optimal structure to accomplish it. Management plans provide the blueprint to achieve the desired structure over time.

3. Expanding the Scope of Urban Forestry

3.1. Linking Green Infrastructure to Economic Development

Review the table of contents for this volume or almost any text on urban forestry for that matter. Techniques for planting, pruning, fertilizing, maintaining, and removing trees as well as conflicts between trees and utilities are often discussed along with root and sidewalk and sewer problems. Some recent texts, like this one, include community involvement to plan for and plant trees in their neighborhood, and techniques for inventories are always discussed. The focus is typically on the trees themselves and what can be done to better manage the individuals without knowledge of the population (the forest) and the social, economic, and ecological forces that affect its condition and long-term viability.

Traditional urban forestry programs deal primarily with the physical improvements in the landscape; those components that were introduced once the natural environment was altered and specifically the tools and techniques that are needed to maintain them. There is seldom a question about the significance of functioning the natural system in populated areas and its importance to maintain the integrity to the extent possible. There is a place for the what and the how of maintaining the urban forest, but to address the increasingly important issue of sustainability (the why), the green infrastructure—the ecological component in populated areas—must be linked to economic development and re-development.

The why will vary from one location to another. Managing tree canopy cover (structure) to reduce summer energy demand (function) while restoring neighborhoods and providing summer jobs and life skills for youth might be a viable option in the city of Philadelphia. In the outlying counties, however, where intensive new development is taking place, environmental and social concerns may require strategies to maintain riparian vegetation and tree cover on upland groundwater recharge areas to reduce downstream flooding and maintain water quality. Issues vary but natural systems can and should be an integral part of the decision-making process that relates to economic viability. This process must lead to the development of comprehensive natural resource management plans to guide land use decisions and operational activities on the ground that will lead to community sustainability.

3.2. Eleven Steps Toward Managing Urban Ecosystems

Effectively managing ecosystems in urban areas requires a systematic process that can ensure the essential information for good decision-making is accounted for. The complexity of ecosystems dictates that specific ecological issues are identified within a study location in order that structural and functional information can be acquired, which addresses those, which issues. This helps to avoid the often repeated mistake of acquiring all the resource data that can possibly be acquired about a particular area only to find that most of them are irrelevant to the intended solution. Although this might appear obvious, it is a common problem. How many communities have developed a "natural resource inventory" that sits on a shelf because no one identified how the data would be used prior to their acquisition.

Through the efforts of the USDA Forest Service Northeastern Area office, in cooperation with the Center for Urban Forestry at Morris Arboretum, an 11-step process, developed by the Revitalizing Baltimore project, was adapted to provide a framework for an Ecosystem Managers Workbook (Morris Arboretum, 1994). Figure 1 illustrates the cyclical nature of this process, which is necessary to ensure that accomplishments continuously contribute toward achieving the vision and goals set forth for the study location. There are a few key points that must be considered when proceeding through the various steps.

The process is driven by a central issue or series of issues. For example, nonpoint source contamination from runoff over paved surfaces is causing algal blooms and advanced eutrophication in creeks and water bodies in the community. With consensus this issue can develop into a vision for clean water with specific goals for aggressive management of critical watersheds, riparian areas, and vegetative cover throughout the community to reduce storm flow and maximize nutrient uptake. This vision and associated goals provide focus for all project activities and must be periodically revisited to ensure that compliance is maintained.

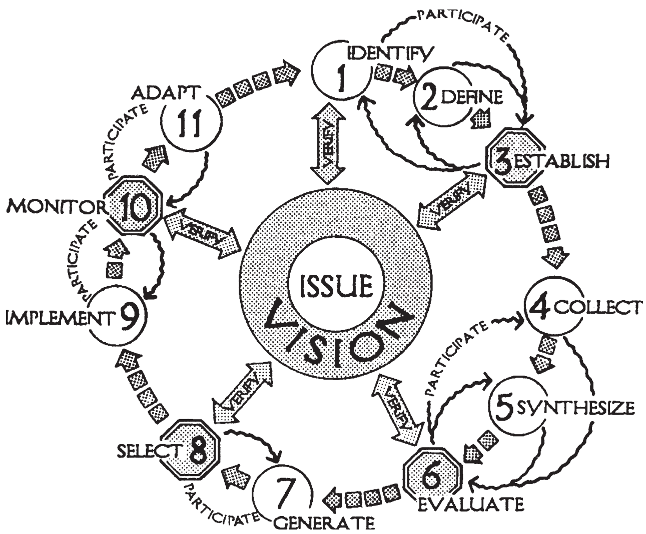

FIGURE 1. Steps in the process. (1) Identify the issues and opportunities to be addressed. (2) Form the project team and define the project scope. (3) Establish a vision and goals through public participation. (4) Identify and collect data to respond to the project goals. (5) Synthesize and analyze data. (6) Evaluate direction and verify goals. (7) Develop alternatives for action. (8) Select the preferred alternative. (9) Implement the preferred alternative. (10) Monitor and evaluate the program. (11) Adapt management strategies to changing conditions.

The process is cyclical, interactive, and adaptive. The stop signs at Steps 3, 6, 8, and 10 serve as reminders for review, testing, and approval. For example, the vision and goals for the project are established through public input in Step 3. This sets the stage for specific data gathering and analysis to determine existing conditions and the effects of alternative future conditions. Step 6 provides the opportunity to reevaluate the vision and goals based on the results of the analysis. Alternative courses of action are then identified and again verified in Step 8 according to the stated vision and goals. Once the project is implemented, a process of monitoring and evaluation will allow for periodic verification that the vision and goals are being achieved. What is learned from project implementation can be used at this point to adapt the management strategy or adjust the vision and goals for the project and continue through the cycle once more.

This process is a tool that can be used at any scale for any project, from restoring a wetland to managing a metropolitan landscape. These is seldom any process simple enough to be linear as is indicated by the 11 sequential steps in the model, especially when volunteers are involved. Decisions frequently have to be made before data are available and analysis is complete. These are the times when it is important to verify that actions to be taken are compatible with the vision and goals for the project.

Disciplines involved and numbers of participants will vary by project, along with complexity of data required, roles in decision-making, and implementation strategies; however, the 11 steps assist greatly in maintaining control of a complex process.

4. Conclusion

4.1. Sustainability as a Central Issue in the 21st Century

The concept of sustainability, that is, meeting current societal needs without compromising the needs of future generations, will continue to remain controversial into the next century because of the abstract nature of the definition. Borman and Likens (1979) relate sustainability to ecosystem stability, which explains the concept in more practical terms. Accordingly, "Every ecosystem is subject to an array of external energy inputs: radiant energy, wind, water, and gravity. All these represent potential destabilizing forces that may destroy or diminish ecosystem organization or sweep away the substance of the ecosystem" (Borman and Likens, 1979:5)." For an ecosystem to grow or even maintain itself (i.e. to remain sustainable) it must be able to channel or meet these potentially destabilizing energetic forces in such a way that their full destructive potential is not achieved within the ecosystem. To the forces mentioned here must be added those introduced through human caused change, as in the Chesapeake Bay example, in what Haber (1990) refers to as the *anthrosphere*. This phenomenon has resulted in transforming the natural landscape to a cultural landscape, which in general obfuscates the natural ecological productivity. Whereas the biosphere relies on cyclical production, consumption, and decomposition, the human-dominated system produces and consumes *technomas* that requires a supply of energy and matter from external sources and in relative terms is not biodegradable. The result is a growing discrepancy between natural orderliness and accelerated human disorder as reflected in environmental degradation (Vos and Zonneveld, 1993; Haber, 1990).

It is in the process of change from natural- to human-dominated systems that the potentially destabilizing forces undermining basic ecological function, and therefore long-term sustainability, must be controlled (Vos and Zonneveld, 1993). The rapid pace of development in this country and around the world will ensure that sustainability will increase in significance in the next century. By protecting and conserving vegetation as a primary ecosystem component, the natural processes of matter and energy transformation can be used to reduce the total impact of human caused change (Brush, 1995). According to Borman and Lukens (1979): "The success of an ecosystem in resisting destabilization may be judged by its ability to minimize the loss of liquid water and nutrients and control erosion" (p. 6). If this is true, urban forestry can play a key role in maintaining a sustainable society.

4.2. The Importance of Context in Natural Resource Decision-Making

It is given that all ecosystems have been impacted to varying degrees either directly or indirectly by human activity; furthermore, ecosystems are constantly in transition and will continue to be (Kaufmann *et al*., 1994). Therefore, an essential step in the process of ecosystem management is to establish existing conditions that can be related to historical conditions for reference in terms of the change that has taken place with regard to structure and its effect on ecological function. From this, existing and potential productive capacity can be determined for use in developing sustainable future options for ecosystem management that can meet societal demands (Kaufmann *et al*., 1994).

Clearly, human-dominated ecosystems must link to the national hierarchical frame-work (ECOMAP, 1993) in order to deal with long-term ecological and socioeconomic sustainability. The continuous exchange of energy, materials, and waste products across the urban–rural continuum must become a part of a comprehensive management framework (Vos and Zonneveld, 1993; Girardet, 1992; Haber, 1990). Context in the urban setting is especially critical since cumulative effects can be severe in a metropolitan region where hundreds of local jurisdictions are making independent decisions about the environment with no ecological framework (US Department of Agriculture Forest Service, 1992).

The Highlands area in Northwestern New Jersey and Southeastern New York States is an example of the need for context in natural resource decision-making. Ninety-two separate municipalities with "home rule" authority granted by the states are making independent, uncoordinated land and resource use decisions that threaten biological diversity and habitat, as well as the water supply for over three million people (US Department of Agriculture Forest Service, 1992). Obviously, there is a need for context in this instance that encompasses both ecological and hydrological boundaries and relates the existing condition of the resource to long-term societal needs. Furthermore, information about the resource base needs to be continually updated and made available to municipalities and the community at large through an institution of government that has some regulatory authority. Unless there is context for natural resource decision making in the Highlands and elsewhere, it is unlikely that sustainability of the resource can be maintained under heavy development pressure.

4.3. Managing Urban Ecosystems: An Expanded Role for Urban Foresters

Presently there are millions of acres of forests in various land use categories in populated areas throughout the United States. These forests, for the most part, are not managed except for the municipal trees on public lands and rights-of-way in the more environmentally conscious communities. Decisions continue to be made daily about the disposition of forested lands to other uses without the benefit of information regarding the impacts to natural systems and the long-term costs associated with such essential societal needs as clean air and water, storm water management, and energy consumption. Lands set aside as open space remain unmanaged and are seldom viewed in an ecological context where they serve to provide diversity and connectivity for plants and animals and related functional uses such as high-quality lumber production or needed outdoor recreational use.

Comprehensive management of the urban forest will not just happen, and ironically it is where the natural system has been substantially altered that management is most needed (Allen and Hoekstra, 1993). This is an unfilled niche that creates a significant opportunity for natural resource professionals who understand ecological concepts and are equally comfortable dealing with social and economic issues. It is not necessary for us to repeat the mistakes of more mature cultures like the Netherlands before recognizing the need for conserving and protecting natural resources in populated areas. By expanding their professional role, urban foresters can fill this niche and significantly contribute to long-term community sustainability through ecosystem-based management.

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