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7 Applying Ecosystem Management to Urban Forestry

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During the 1990s, the United States Department of Agriculture Forest Service shifted from commodity production management to ecosystem-based management (Overbay, 1992). Although definitions of ecosystem-based management vary by objectives, the principle had four primary elements: (1) maintaining viable populations of native species, (2) representing native ecosystems across their range of natural variability, (3) maintaining ecosystem processes, and (4) ensuring ecosystem goods and services for future human generations (Grumbine, 1994). In general, ecosystem management approach becomes a way of thinking more broadly about a system (Yaffee et al., 1996). For example, a forester must consider how management activities affect not only timber production but also ecosystem processes, biodiversity, and natural populations, all of which influence forest productivity. This way of thinking enables managers to look at the entire forest as a single entity and assess how management goals and objectives affect ecosystem integrity.

During the 1990s, urban forestry in the United States began to shift from single-tree to ecosystem-based management (Zipperer et al., 1995). This new approach recognizes the importance of urban vegetation (both public and private) as part of the urban ecosystem and as a source of many ecological services and benefits (Nowak and Dwyer, 2000). These benefits include cleaning air and water, enhancing human health, and providing wildlife habitat, recreational opportunities, and aesthetics. By taking an ecosystem approach to management, urban foresters can maximize benefits from the forest while minimizing the cost to maintain it.

Yet, an urban forester manages by altering the structure of only public trees through single-tree management. Does this mean that an ecosystem-based management is not a viable objective for urban forest management? Throughout the International Symposium on Urban Forestry and Eco-Cities held in 2002, speakers promoted the need to take a holistic approach to management and the need to better understand the social and ecological processes influencing the livability of a city. This chapter provides a succinct overview of ecosystem principles as they pertain to urban landscapes, and applies the theory of vegetation dynamics as a means of clarifying for managers how they may take a holistic approach through single-tree management.

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Ecosystems

An ecosystem is defined as a spatially and temporally explicit place that includes all the organisms, all abiotic factors in that environment, and their interactions (Likens, 1992). For an urban ecosystem, this includes the entire set of social, ecological, and physical components that define an urban area. One might ask, What is an urban ecosystem and how might it differ from other ecosystems? McIntyre et al. (1990) reviewed the concept of "urban" and concluded that no single definition exists because of the different perspectives of those who study or work in urban systems. I propose that rather than trying to define an urban area spatially, consider thinking of it as a system where ecological, physical, and social patterns and processes interact to create a unique environment. This environment represents both the green (e.g., vegetation) and gray (e.g., buildings and roads) infrastructure. In their paper on urban ecosystems, Pickett et al. (1997) presented a simple model to reveal the interconnectedness of social, ecological, and physical components. They asserted that by changing one component, the other components are directly or indirectly affected. So, from an urban forest management perspective, a manager, by altering some aspect of ecological structure (e.g., composition and diameter distribution of trees), can influence the social and physical components of the system, and all these factors (ecological, social, physical) must be taken into account when making management decisions, particularly since they will affect the extent of ecosystem services provided by the forest.

To achieve an ecosystem approach to management, the entire urban forest needs to be considered. A manager accomplishes this by looking beyond the particular management site and evaluating the effect of the site on adjacent land uses, and congruently, the effect of adjacent land uses on the site. In other words, the site should not be viewed independently of the context in which the site occurs, since context will affect the site and the site will affect its context. By viewing management activities from this broad perspective, the manager moves beyond simply planting a tree at a particular site or location, and asks how this activity affects ecosystem process and subsequent services to the site and adjacent areas. This perspective is important because an ecosystem is an open system, in which energy, materials, and organisms move into, through, and out of the system. By altering the urban forest structure or the physical environment of the site, the manager influences this movement. For example, by increasing the canopy cover by planting trees, a manager can influence the amount of particulate material and rain intercepted by the trees. A greater interception of material leads to cleaner air and less storm runoff. By taking a broad perspective, a manager can evaluate potential planting sites in the context of surrounding vegetation and ask if the proposed planting achieves the desired management goals and objectives, or if resources should be directed to other sites. So, a broad perspective enables managers to prioritize sites for planting, and this may maximize benefits while minimizing costs (also see Chapter 13).

To illustrate this point, I will use a figure representing the vacant lots and buildings in Baltimore, Maryland (Fig. 7.1). One objective for an urban forester might be to

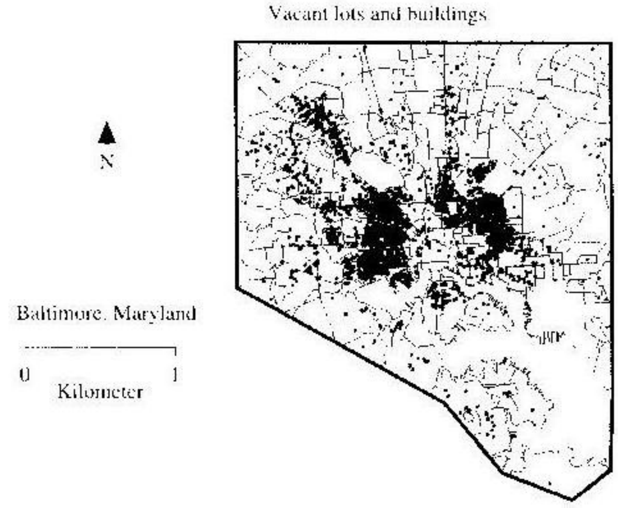

Fig. 7.1 A map showing locations of vacant lots and buildings in Baltimore, Maryland. (From Parker et al., 1999.)

afforest vacant lots, but which ones and which ones first? Which vacant lot has the greatest effect on water quality, on neighborhood well-being, and on city beautification? By asking these questions, the manager can determine which lots would most improve the quality of life in Baltimore. The link between site management and context could only be achieved by taking a broad perspective and asking what key ecosystem processes (social, ecological, and physical) influence the site and how these processes can be modified or enhanced by afforestation.

Managers should also keep in mind that ecosystems are dynamic. They are continually changing because of management activities, species natural history, natural succession, and natural and human disturbances. Throughout a city, public trees are being planted to maintain canopy cover and removed to reduce safety risks. These activities represent change. Furthermore, each city has its own disturbance regime. A disturbance regime defines the type, size, frequency, severity, and dispersion of disturbances influencing the city. For example, hurricanes can significantly alter the structure of an urban forest (Duryea et al., 1996). Although this disaster can be catastrophic to human well-being, it may provide the urban forester with a unique opportunity to restructure the forest by creating new planting opportunities, changing species diversity, and balancing its age structure (see Richards, 1983). By restructuring the public forest to meet an objective of sustaining or enhancing ecosystem goods and services, a manager may begin to take a long-term view of the forest and its benefits, and how to optimize those benefits.

An ecosystem approach enables managers to see how their activities of planting trees are interconnected with the entire urban forest and the ecosystem goods and services the forest provides. Similarly, an ecosystem management perspective plans for changes that may occur through natural and human disturbances. This holistic approach has been echoed throughout the International Symposium on Urban Forestry and Eco-Cities in 2002 and called by various names: ecoscape, ecoindustry, and ecoculture. No matter what it is called, a holistic or ecosystem approach to management creates a framework for improving the livability of our cities by maintaining or enhancing ecosystem services through influencing ecosystem structure and altering ecosystem processes. But a manager must still consider how to link ecosystem management to single-tree management. I propose that we adapt the concept of vegetation dynamics to urban forest management (Fig. 7.2 and 7.3).

Vegetation Dynamics

The concept of vegetation dynamics was proposed to account for successional changes on a site at a single species or individual level (Pickett et al., 1987a,b). The concept has three primary components: site availability, species availability, and species performance (Fig. 7.2). Succinctly, from a natural succession perspective, site availability refers to the creation of space for an individual to germinate, grow, and reproduce. Sites become available through the death of an individual or through a disturbance (Brand and Parker, 1995). Disturbance type dictates the frequency and size of site formation. Species available to colonize these sites currently exist in the seed bank or disperse there from adjacent areas. Once an individual species is planted on a site, its performance determines its survivability. Factors influencing survival include species autecology, environmental conditions and resources, and interactions with other site elements, such as other species. Autecological factors include life history and phenotypic plasticity. Examples of environmental conditions include climate, air pollution, heavy metal toxicity, and site history. Examples of resources include light, nutrients, and water. Examples of species interactions include competition, herbivory, disease organisms, mutualistic symbioses, and allelopathy. I will use this framework to discuss the application of ecosystem management to urban forest management in greater detail.

Site Availability

Within the urban landscape, site availability represents an array of sizes ranging from a single-tree pit, to a vacant lot, to an entire urban park (Zipperer et al., 1997) (Fig. 7.3). For example, in Chapter 8, Nerys Jones describes the reforestation of derelict industrial sites. To promote natural recruitment of species, industrial debris was removed and soils were prepared. As predicted by the vegetation dynamic model, an array of native and nonnative species from adjacent areas colonized these sites (also see Chapter 23). Local residents now use these "naturalized" areas for recreation.

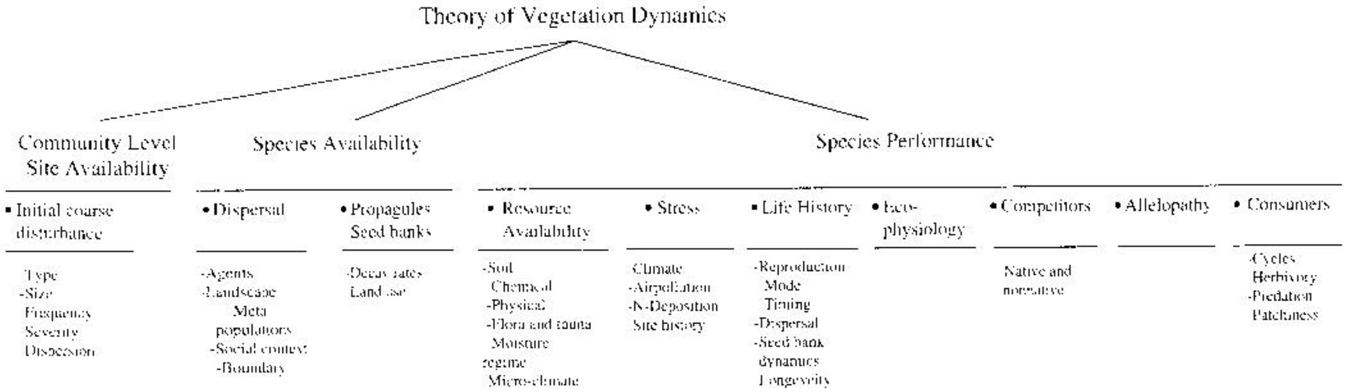

Fig. 7.2 Components of the theory of vegetation dynamics used to account for successional changes. N, nitrogen. (From Pickett et al. 1987a,b.)

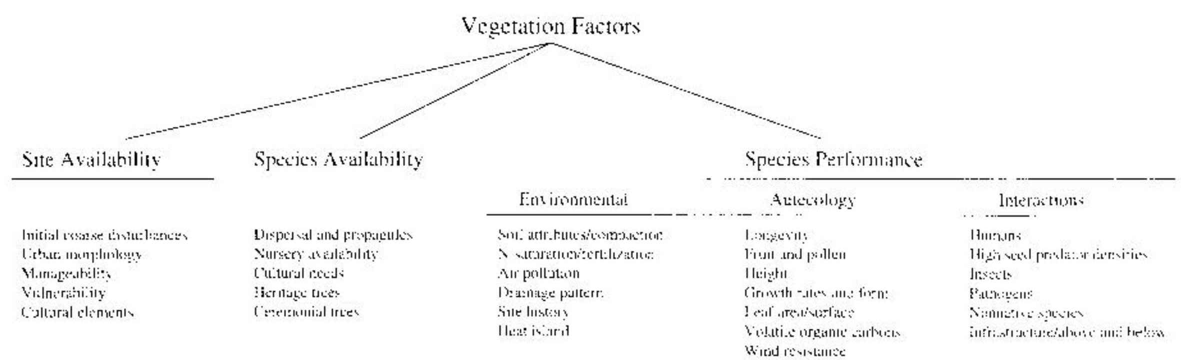

Fig. 7.3 Theory of vegetation dynamics modified for application of ecosystem management in urban landscapes by incorporating elements of the urban ecosystem used in the management-decision process

Site availability also is applicable at a citywide scale. The City of Shanghai demonstrated this by creating three new urban parks where none existed before. Site selection was based not only on the logistics of where to place a park but also on the social context of the site. These new parks occupy sites that offer an array of social and ecological benefits not previously enjoyed by residents (also see Chapter 20).

The selection of sites for these parks, as well as sites for single-tree management, is based on urban morphology. Urban morphology is the pattern of urban development, both vertically and horizontally (Sanders, 1984), and includes the buildings, streets, sidewalks, parking lots, and other human structures. Where human structures and surfaces already occur, the possibility of planting spaces is eliminated unless considerable effort and cost are expended to remove existing structures or surfaces. Therefore, the more densely packed a city is, the fewer the places for trees to grow. In Baltimore, for example, urban foresters use a geographic information system (GIS) to select vacant lots to rehabilitate (see Fig. 7.1). The selection process included not only biophysical factors but also social factors. Recognizing that community members were essential to the success of their projects, foresters worked with local community leaders to plant and maintain sites (Grove and Burch, 1997). Through this socioecological partnership, managers rehabilitated sites and community leaders revitalized their neighborhoods (also see Chapters 9 and 12).

Contextual elements and processes influence a site and its availability. For example, in Chapter 15 James Kielbaso discusses the importance of site manageability, and the benefit–cost ratio of managing a site. Shanghai created urban parks where there were none before. Only time will tell if the benefits of creating these parks will exceed their cost for development. Likewise, the selection of sites to plant trees must account not only for manageability but also other contextual influences such as vulnerability (damage by humans and natural events such as droughts, frost, and pollution) and cultural elements. In Chicago, forest managers work with local planners to maintain the connectivity of natural areas not only to maintain genetic flow among natural populations, but also to provide corridors for recreation (Gobster and Hull, 2000).

Planting sites also become available through catastrophic disturbances. Not only can these disturbances have devastating effects on the existing urban forest, but they also can create opportunities for the urban forest manager to replant, balance age and size structure, and enhance species diversity. Storms also provide insights into which species are capable of withstanding local disturbances. In their work, Duryea et al. (1996) assessed how different species survived a hurricane and used this information to make recommendations for future tree plantings in affected areas.

Species Availability

In a natural system, species availability depends on dispersal from adjacent areas and emergence from the soil seed bank. For the urban landscape, species availability is more complex and involves both ecological and social elements (Fig. 7.3). Species dispersal and seed banks play a critical role in reforesting abandoned or restoration sites (Robinson and Handel, 2000) and colonizing an existing remnant or regenerated forest patches. Because of the abundance of nonnative species growing in the urban landscape, many of the species colonizing remnant and regenerated forest patches are often nonnative (Moran, 1984; Guntenspergen and Levenson, 1997; Zipperer, 2002). This observation is of particular importance when considering new species for planting. One of the primary avenues for introduction of nonnative species into remnant vegetation is arboricultural and horticultural plantings (Reichard and White, 2001). As managers, we need to ask how our actions will affect not only the site but also the area around it. In other words, how does site content affect site context? Because ecosystems are open systems, propagules from plantings can be dispersed into remnant and regenerated forest patches of vegetation, potentially changing their species composition and structure and subsequent functions in the broader landscape (Rudnicky and McDonnell, 1989).

The debate over whether or not to use nonnative species in urban plantings can be acrimonious at times. The premise for using nonnative species is that the environmental conditions in urban landscapes have been altered, and native species can no longer survive or compete with nonnative species (MacDonald, 1993). However, the data documenting native species responses to urban conditions are limited. Realizing nonnative species may become invasive, selection protocols need to be implemented to eliminate introductions of invasive species when selecting nonnative species for plantings (Reichard and White, 2001).

In urban landscapes, social factors play a key role in species availability and selection. For example, nurseries may stock only a limited number of species, thus limiting species selection for plantings. Another presentation at the International Symposium on Urban Forestry and Eco-Cities in 2002 described new nurseries that are being created around various Chinese cities to meet projected demands of future tree plantings. Unfortunately, it seems that most of these nurseries contain a limited number of species and they were principally nonnative. From a holistic perspective, species diversity plays an important role in maintaining a system's resiliency and stability (Tilman et al., 1997). If the purpose of management is to enhance ecosystem services, then activities (e.g., greater species diversity for nursery stock) that achieve this goal are desirable and should be encouraged. Also, since many of the species planted in urban landscapes are cultivars, managers need to recognize cultivars' limited genetic diversity and account for it when selecting which species to plant.

If managers have a diverse selection of species to work with, they will be able to select appropriate species to meet site and contextual needs. However, plantings in our cities not only need to meet biological diversity criteria, but also need to balance management costs and capabilities (Richards, 1983, 1993; Nowak et al., 2001). This balance may reduce the number of species available to managers because of the cost of subsequent management. However, over time a manager can develop a list of species to meet diverse management needs once new species have been tested under different site and contextual conditions (see Chapters 24 and 25).

Other social considerations include conserving heritage and ceremonial trees (Jim, 2005a,b; also see Chapter 9). Heritage trees represent species that have local, regional, or national significance. For example, American Forests, a nonprofit organization in the United States, offers homeowners an opportunity to plant seeds and seedlings from historically important trees (http://americanforests.org/). In the United States, species may be selected to memorialize victims of homicides or accidents. Often these species may represent the favorite tree of an individual or an entire community. With time, these memorial plantings can become an important component of the social fabric of a neighborhood, town, city, or state.

Species Performance

Urban forest managers can influence site and species availability, but they have little influence on species performance (unless the species is genetically manipulated). However, the manager can increase the probability of tree survival by selecting the right species for site and contextual conditions. In the urban environment, examples of site content factors that affect species performance include soil compaction, poor nutrient availability, minimal planting space, and inadequate drainage (Fig. 7.3). Through best management practices, managers can minimize the negative impacts of these factors, thus decreasing mortality and increasing the effectiveness of plantings (Miller, 1988).

Contextual influences include not only air pollution, pathogens, and urban heat-island effects but also new development patterns. Air pollution assails the health of individual trees and the entire urban forest. By neglecting site condition or selecting the wrong species for those conditions, the manager may inadvertently increase its susceptibility to insect and pathogen outbreaks. As these outbreaks develop, they may move beyond the urban landscape into rural forests, hence increasing economic losses beyond a municipality's boundary. For example, a southern pine bark beetle infestation in Florida originated in Gainesville and progressed outward into neighboring counties. Although the beetle is native and was not considered a pest, environmental circumstances (4 years of drought), new development patterns, and stress from the urban environment created favorable conditions for a species outbreak. Similarly, a change in urban morphology (e.g., adding more buildings or developing vacant lots) may alter microclimatic conditions and increase heat-island effects (see Chapter 6). The additional heat load adds to the existing environmental stresses on individual trees.

A species' autecological traits not only are important for its survival in an urban environment but also have important contextual value. For example, a species' leaf area, emissions of volatile organic carbon compounds (VOCs), pollen production potential, and longevity are important elements when management objectives include reducing particulate matter and air pollution. A tree with high leaf area, and low VOC emission can improve air quality by intercepting more particulate material, cooling ambient temperatures through evapotranspiration and shading, and releasing lower VOCs than a tree without such traits. So, when selecting individuals to plant, the manager must consider not only species tolerant of high temperatures, but also those species that may contribute to ozone production from VOCs (Nowak et al., 2001) or high pollen loading to susceptible people in the vicinity. Likewise, longevity and growth rates are important traits influencing carbon sequestration. Slower growing species, such as those in the genus *Quercus*, may sequester carbon less quickly than a fast-growing species, such as those in the genus *Populus*, but because of their greater longevity, some *Quercus* species can sequester and store carbon for a longer time. Similarly, context will influence whether trees bearing fruits and nuts are to be planted. In one neighborhood, fruits and nuts may be viewed as a nuisance, whereas in a different neighborhood they may play an important role in supplementing local dietary needs, as occurs in agroforestry but in an urban landscape. As managers, we need to realize that matching species to the social context may be just as important as matching species to site conditions.

A manager also needs to acknowledge the interactions within and among ecosystem components that influences species performance. These interactions are both natural and anthropogenic. For example, a street tree needs to be large enough to minimize vandalism (e.g., breaking branches, bending, pulling the tree out of the ground). Natural interactions include increased seed predation and herbivory, which can significantly affect reforestation projects. With the planting of nonnative species in urban landscapes, competition may increase between native and nonnative species in colonizing available sites within forest remnants. Similarly, homeowners and managers may select nonnative rather than native species, thus reducing the likelihood of nurseries carrying more native species (a negative feedback loop reinforcing continued sale of nonnatives in nurseries). Also, due to international imports, urban landscapes are often exposed to new pests and pathogens (e.g., cities were Dutch Elm disease and chestnut blight infection foci in the 20th century). A recent example is the presence of Asian longhorned beetle in New York City, Chicago, and some cities in Connecticut (http://www.na.fs.fed.us/fhp/alb/index.shtm). This pest, which was unintentionally introduced on wooden pallets and boxes from China, has spread to the urban forests of several cities in the U.S. By not accounting for the variety of interactions that affect species performance, planting and restoration projects may fail.

In previous sections, I have modified Pickett et al.'s (1987b) and Pickett and McDonnell's (1989) theory of vegetation dynamics to include attributes associated with urban forest management (Fig. 7.3). This is not to say that the original vegetation dynamic model should be ignored, but rather, it should be complemented with additional ecosystem level attributes particular to urban areas that influence urban forest management. Similarly, this list of attributes is not meant to be exhaustive, but rather meant to increase a forest manager's awareness of factors influencing management actions and outcomes in urban areas. Managers will need to add to this list to account for the unique conditions and interactions created by the ecological, physical, and social components in their own urban landscapes that affect site availability, species availability, and species performance.

Conclusion

As urban forest managers, we need to think more broadly about the landscapes in which we work to identify the key ecological processes affecting a site, evaluate how they will affect our plantings, and assess how our plantings will affect these processes. Through our management, we can alter urban forest structure to improve ecological processes, thereby enhancing ecosystem goods and services. To meet these management goals, managers need to identify both site content and context factors when selecting species and sites. To be effective, an array of diverse species is needed to maintain urban forest stability and resilience. This diversity, however, will undoubtedly be tempered by management costs. Through proper education, managers and other individuals involved in urban forest management (e.g., nursery growers, politicians, and residents) can maintain a healthy urban forest to yield benefits for healthier lives.

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