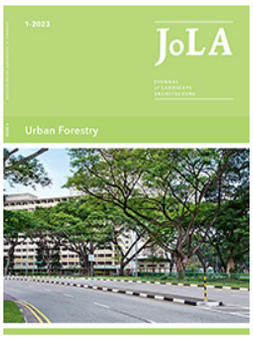

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Beyond the axe: Interdisciplinary approaches towards an urban silviculture

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Abstract

Forests in cities, from remnant woodlands to designed natural areas, are common and abundant. Ecologically similar to rural forests, these landscapes lend themselves to the principles of traditional forest management, such as silviculture. But the application of silviculture to forests in cities, at least in the United States, has long been met with resistance: as far back as Olmsted's Central Park experiments with 'planting thick and thinning quick', public sentiment has been protective of trees, even when forest health would have benefitted from such treatments. Urban silviculture is a conceptual framework and a renewed call for a systematic approach to managing forests in cities that addresses cities' socioecological context through adapted practices that integrate other disciplines, including design. Using emerging science and case studies, we explore how silviculture and landscape architecture, two allied yet often-alienated disciplines, can engage to create socially responsive evidence-based approaches that enhance the design, management and resilience of forested landscapes in cities.

forests in cities / urban silviculture / adaptive management / landscape architecture / ecological design / urban afforestation

Introduction

In 1876, Frederick Law Olmsted, who led the design and installation of so many large forest parks in US cities, wrote to the president of the Central Park Commission in New York City with a proposal that the park act as a kind of forestry laboratory:[1] 'A Museum of Arboriculture arranged and catalogued suitably for profitable study.'[2] Olmsted wrestled with the need for more knowledge to better manage forests in cities, as well as a means of communicating the need for continued management to the broader public, a plea that resonates today.

Olmsted had observed a disconnect between the need for sustainable forest management, which included occasional forest thinning, and the public's aversion to seeing forest management in action. He became so frustrated by how vehemently the public opposed cutting trees in his new public parks, that he co-wrote an essay titled 'Observations on the Treatment of Public Plantations, More Especially Relating to the Use of the Axe',[3] which drew on quotes from several prominent experts in forest management to defend the necessity of tree cutting and thinning for long-term forest health in cities. When he wrote 'The Use of the Axe', Olmsted was writing from the position of a designer acting as a primary decision maker in the realm of establishing urban forests, soliciting guidance from the established practice of forestry and land management. In fact, when Olmsted was approached around the same time to design George Vanderbilt's Biltmore estate in North Carolina, this interest in forestry expertise led him in 1891 to hire a young forester by the name of Gifford Pinchot to guide the methodical establishment of the Biltmore Forest (Pinchot would go on to become the first Chief of the United States Forest Service). Together, Olmsted and Pinchot devised a forestry programme that established a series

Figure 1 The urban forest refers to all trees in the city and includes multiple subcategories of site types that differ in structure, ecology and management.

of plantations, carefully sited both for their visual effect and to improve the poor and depleted soils around the Biltmore site, and which included 'improvement by cutting' alongside profitability and steady yields as guiding principles.[4] This collaboration between a landscape architect and forester on a seminal project for both landscape design and scientific forestry is an inspiration for the possibilities that exist today for these two fields to work together as we imagine a closer relationship between the design and management of forests in cities.

In the nineteenth century, large forest parks and municipal park systems represented radical design interventions in the urban fabric. More than 100 years later, forests in cities are commonly the domain of natural resource managers and are often neglected. Landscape architects, typically involved in the early stages of the establishment of forested parks and designed natural areas, rarely stay involved in their long-term management. And yet, it is not just the initial stage of forest design that warrants a spatial sensibility—especially if we think about forests in cities as being continually reshaped by people and the urban environment. On the other hand, making sure that forests in cities are a sustainable and resilient piece of the urban fabric will no doubt require innovative forest management practices—responsive to the complex social and ecological dynamics of cities. In the United States, there remains a need for a unified practice of forest management and design based on evidence-based approaches, just as Olmsted sought to establish in Central Park. To achieve this, we, as an interdisciplinary team consisting of a landscape architect and forest ecologists, revisit this need and explore the potential of *urban silviculture*—a systematic framework for applied forest ecology in cities.[5] Here, we present recent developments in the state of applied ecological research that can inform urban silviculture, as well as landscape design case studies that suggest approaches for integrating this new ecological knowledge into designed landscapes. The goal is to expand the toolkit of designers operating in this space, and suggest beneficial avenues for future interdisciplinary collaboration. By reviewing emerging urban ecological research, management methods and design case studies, we examine how the development of an urban silviculture may not only serve as a resource for designers, but be better realized as a practice by integrating the expertise of landscape architects in crafting more publicly legible, publicly accessible, more proactively managed and therefore more resilient forests in cities—perhaps bringing the two professions back to their origins of interdisciplinary collaboration here in the United States.

Forests in cities and the case for an urban silviculture

Over the past two decades, the 'urban forest' has become a commonly accepted term to describe all the trees in the city,[6] including everything from street trees to trees in highly managed and landscaped parks and residential areas, to forested natural areas—landscapes that are all quite different from one another in their composition, structure and management approach (Fig. 1). Here, we focus specifically on forests in cities, which from an ecological perspective are the urban forest typology most similar to non-urban forests. Forests in cities, sometimes referred to as urban woodlands, forest patches or forested natural areas, are landscapes that are dominated by woody vegetation and where natural regeneration of future trees and woody plants are not limited by management regimes (such as mowing).[7]

For many cities, especially those located in forested biomes, forests in cities are common and abundant, although frequently overlooked. In the United States for example, there are more than 1.7 million acres of forests embedded in urban landscapes and more than 84 per cent of city parkland is categorized as natural area.[8] Increasingly, these forest landscapes are being recognized for their multiple and potentially disproportionate contributions to urban ecosystem services, including heat island and stormwater mitigation,[9] carbon sequestration and storage,[10] and habitat provision.[11] From a social perspective, these sites provide opportunities for recreation, promote well-being and can serve as a primary interface with nature for many urban residents.[12]

When considering the design and management of forests in cities, we might further categorize these landscapes into designed forest parks, afforestation sites, remnant forest and spontaneous forest (Fig. 2). *Designed forest parks*, where the role of landscape architects is central, often originate from planting and include *large forest parks*, such as those created as part of

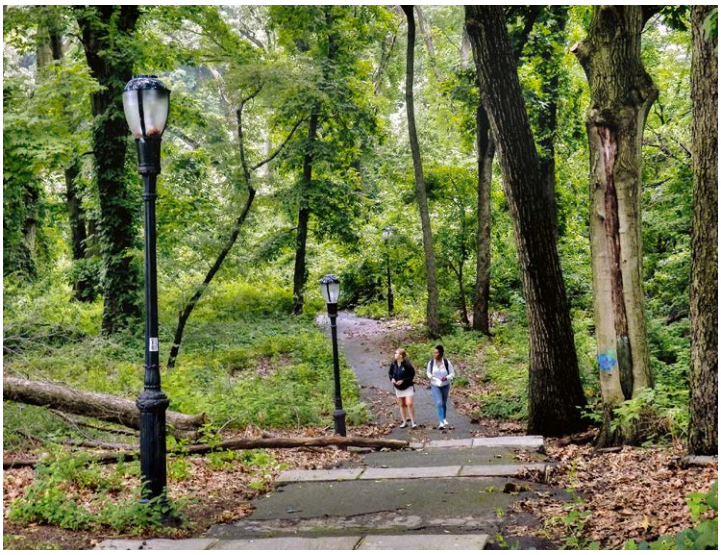
RICHARD A. HALLET


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Figure 2 Operational classification of forests in cities. Clockwise from upper left:

designed forest parks, including older forest parks and contemporary designed natural areas (Forest Park, New York City);

remnant forests that were not planted and have no history of urban land development (Van Cortlandt Park, Bronx, New York City);

spontaneous forest, where unplanted trees establish on previously urban land cover types (North Brother Island, New York City);

afforestation sites, primarily overseen by land managers and municipalities (Freshkills Park, Staten Island, New York City).

municipal park systems in the United States, as well as the contemporary projects that we refer to as *designed natural areas*. The latter have a goal of achieving complex species assemblages and structure that emulate a natural forest state, but are typically smaller than legacy forest parks and located on dense urban sites that are intended to offer an experience of nature for large numbers of visitors. *Afforestation sites* are more recent and reflect greening efforts to increase the tree canopy across city land—these sites are often implemented and controlled by natural resource managers.[13] *Remnant forest* and *spontaneous forest* are both unplanted, but differ in land use history and disturbance. Remnant forest may include old growth or secondary forest located on sites that have no prior urban land use and are frequently located on conserved or undevelopable land (for example wet sites and steep slopes). Spontaneous forests occur on sites with a history of urban land use, such as vacant lots, landfills, former industrial sites or railways.

Except for designed natural areas, which are often intensely managed, forests in cities are frequently left undermanaged. Often this is the result of limited funding and staffing, but also a legacy of the perspective (especially in the United States, with its history of wilderness conservation on formerly logged landscapes) that forests do not require active management and can simply be left alone to grow without intervention—a romantic misconception that scientific studies have refuted.[14] Given their similarity to their rural counterparts, forests in cities lend themselves to the adoption of existing ecological forest management frameworks, such as silviculture. Silviculture is the science and art of growing trees and forests and is one of the world's oldest land management practices.[15] Although many associate silviculture with timber harvest practices, at the most basic level it is the application of ecological principles in controlling forest composition, health and growth.

Despite its relevance to forests in cities, the adoption of silviculture, particularly in the United States, is not commonplace in the urban context. And although there are exemplary leaders in implementing urban silvicultural practices,[16] these efforts are often singular and do not exist within a system of evidence-based practice that can facilitate scalability and knowledge transfer. In recent years, an 'urban silviculture' has been proposed as a framework to help formalize management practices.[17] Creating urban silvicultural systems may start by relying on traditional silvicultural practices; however, the socioecological context of urban ecosystems (with their anthropogenically altered hydrology, soils, species composition, climate and disturbance histories, for example)[18] means that novel approaches may need to be created to deal with urban conditions. This extends to adjusting forest assessment methods, goal setting and operational activities. Urban silvicultural systems also account for people and the diverse values of various stakeholders that interface with forests in cities. It is here that urban silviculture may be most distinct in its approach and will benefit from integrating the expertise of other urban practices, including landscape architecture and design.

The potential of urban silviculture in design

While ecology constitutes one of the core competencies of contemporary landscape architecture practice, the integration of ecological theory and dynamics into landscape design is still emerging, and incomplete. Designers are still often trained to deal with sites as horticultural compositions, setting out every plant with the expectation of continued growth, but not always thinking through how a plant community develops, changes and regenerates over the long term. The potential contribution of an urban silviculture to a landscape design approach is in many ways an extension of the adoption of ecological perspectives into landscape architecture—but in this case tailored specifically to forest landscapes and systems. Conceptually, the urban silviculture framework establishes an ecological (and potentially a design) foundation for understanding and working with forests in space and time. Operationally, silviculture can provide designers with a toolbox of strategies and prescriptions for designing and establishing new forests and manipulating existing forest structure and composition, from early stages of forest establishment to mature canopy. Silviculture extends the management and design timeline, giving designers tools to think about forest dynamics, including how forests respond to disturbance, and to think beyond the first generation of planting.

As a practice, silviculture leverages—or, through manipulation of existing vegetation and site conditions, mimics—the ecological dynamics of forests (that is, 'stand dynamics') to sustain or facilitate the establishment of desired tree species and forest structure. Silviculture engages different stages in forest stand dynamics, including a) 'stand initiation', where new trees are established, b) 'stem exclusion', where saplings compete and naturally thin out as they mature, c) understory re-initiation, where new reserve trees establish, and d) disturbance events, which vary in spatial and temporal scale including fine-scale mortality, such as the loss of single mature trees to natural causes, or stand initiating disturbances (such as a tornado or fire), which result in the loss of large areas of forest canopy cover that return that area to the stand initiation phase (Fig. 3).[19] In its most basic sense, forest stand dynamics is an expansion of the ecological succession concept that accounts for the continuous change in forest states over time. Silvicultural treatments are purposeful actions that target the establishment of specific species, communities and forest structure (the inclusion of different strata or age classes, for example). The treatments may occur when establishing new forest (direct seeding, planting) or mimicking disturbance events (such as canopy tree removal) to establish new species or different age classes in a forest (Fig. 4a).

When applied to forests in cities, silvicultural approaches may need to be adapted to take into account the urban ecosystem context and potential stressors that can alter the species composition, structure and regeneration potential of forests (Fig. 4b). This has been most readily observed and tested in stand initiation prescriptions, often through afforestation projects, where direct planting is the standard practice. Site factors such as compacted soils and invasive plants may limit the natural establishment of native trees and even inhibit the survival and growth of planted trees. Olmsted's call to 'plant thick and thin quick' is itself an adapted approach to jumpstarting forest establishment. Contemporary ecological studies have begun to test and develop a suite of site treatments and planting strategies that facilitate natural regeneration of native trees on vacant lots, brownfields and/or landfills. For example, in a designed experiment, Alex Felson et al. sought to optimize afforestation planting practice by identifying plant palettes and soil amendments that improved tree survival and growth,[20] as well as soil restoration[21] and native plant recruitment.[22] Seeking to promote native tree afforestation at scale, George Robinson and Steven Handel demonstrated the potential of applied nucleation,[23] which involved planting islands of fruit-bearing trees at the Fresh Kills landfill

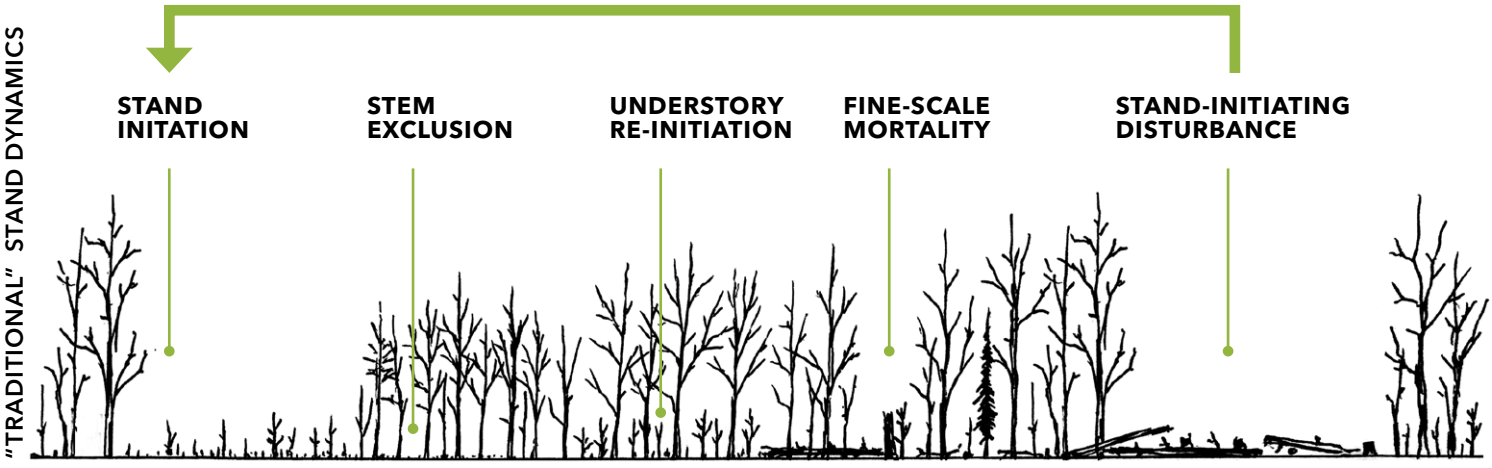

Figure 3a Forest stand dynamics identifies important stages in forest establishment and change over time, including stand initiation (seedling establishment), stem exclusion (self-thinning of saplings), understory re-initiation (seedling establishment in closed-canopy conditions), fine-scale mortality (loss of single canopy trees), and stand initiation disturbances (events that alter canopy at scale and return that area to the stand initiation stage). Note, over time and across a forest, these processes result in a complex patch mosaic.

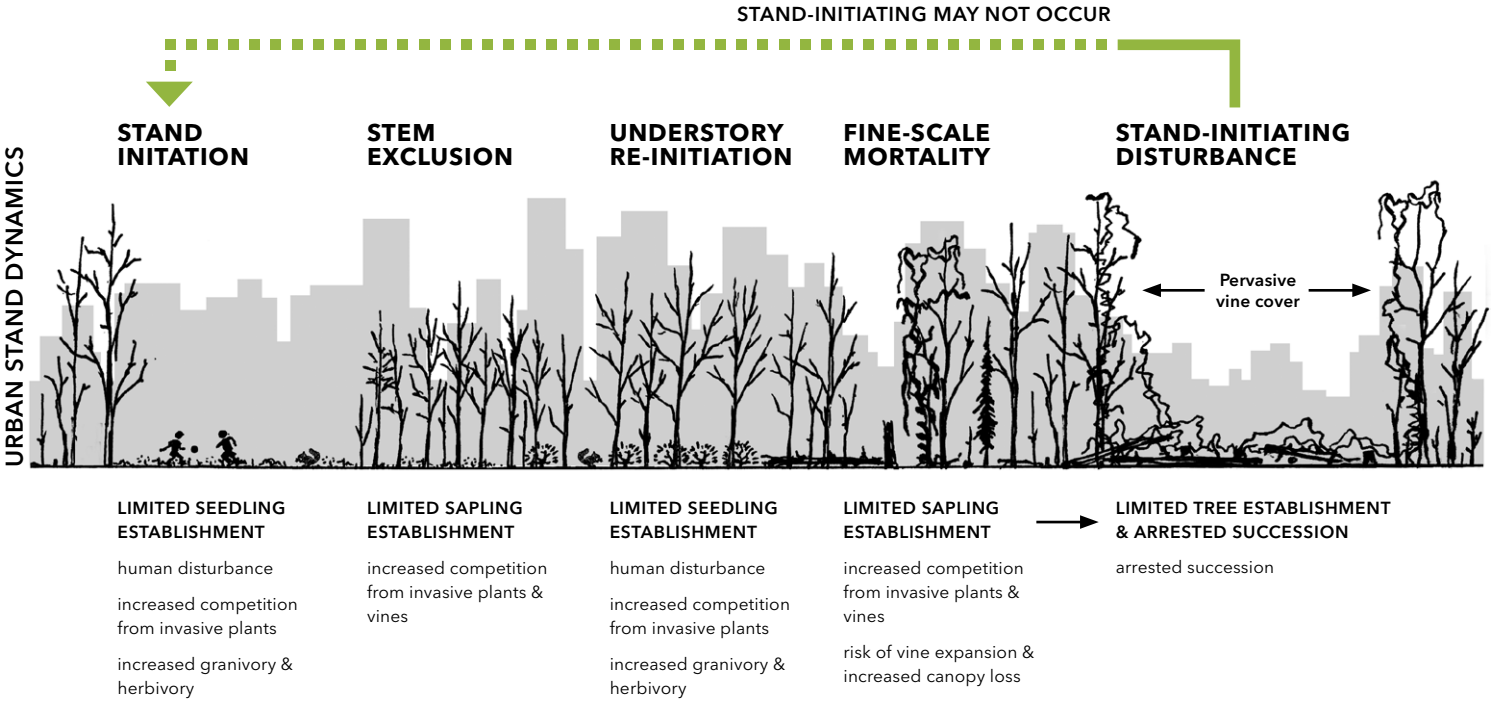

Figure 3b In cities, forest stand dynamics may differ due to the socioecological context. These factors can result in reduced tree establishment and survival over multiple stages of stand dynamics. As a result, recovery from small-scale mortality and stand-initiating disturbances can be inhibited and may even result in arrested succession and pervasive vinelands.

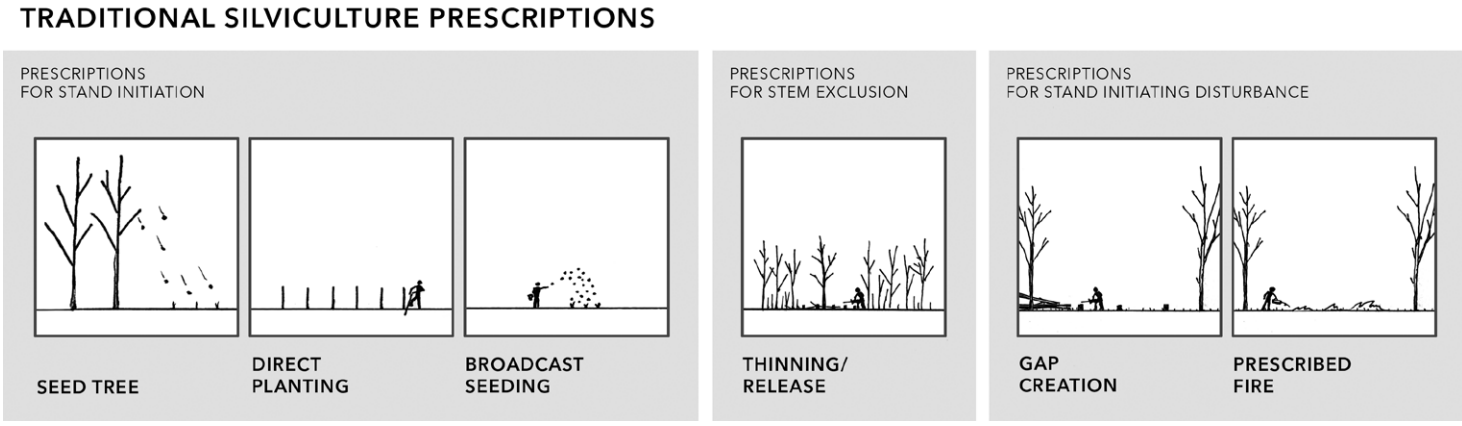

Figure 4a Traditional silviculture prescriptions mimic forest processes and critical stages in stand dynamics.

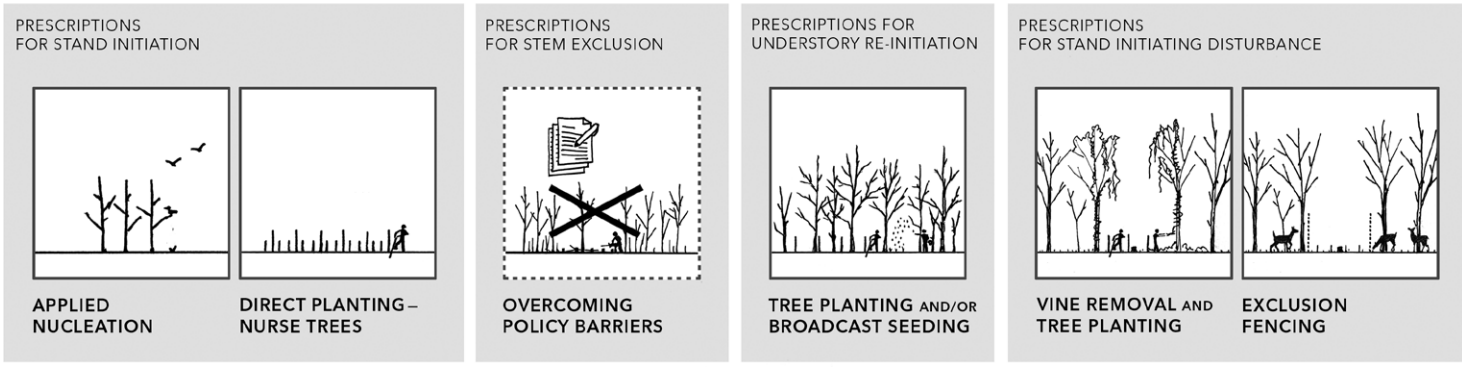

Figure 4b Urban silviculture may need to adapt traditional prescriptions to overcome the multiple, co-occurring and exacerbated impacts on forest conditions.

in New York City to attract birds, and with them additional seed sources. Similar to the seed tree model of silviculture, this approach considers seed dispersal mechanisms (such as the wind and birds) to facilitate the natural regeneration of native vegetation in the surrounding landscape. By creating perching sites for birds, seed dispersal and tree establishment may be directed and potentially accelerated, limiting the number of trees required in an afforestation planting and acting as an alternative to direct planting an entire site.

Less understood is how later stages in forest dynamics, such as fine-scale mortality (single canopy tree removal, for instance) and stand-initiating disturbance, should be approached in urban landscapes. Many traditional treatments rely on mimicking disturbance, often by creating openings, to establish desired tree species or forest structure (height, age class). For example, to promote oak regeneration, one traditional approach includes selectively removing mature trees, thereby increasing light to the forest floor which, in turn, facilitates oak seedling establishment. In cities, gap creation is risky and often results in rapid invasion by undesirable plant species that prevent tree establishment. Ultimately, this may result in a state of arrested succession where a site is dominated by vines for an indefinite period (Fig. 5). From a silvicultural perspective this is significant—urban silvicultural practices are more likely to be successful if they account for these vulnerabilities by creating approaches that accelerate gap recovery and suppress invasion. This is the focus of the Northeast Urban Silviculture Network, which is testing novel approaches to restore oak forests by taking advantage of existing gaps in forests (caused by mature tree decline or blowdown).[24] This network, led by the USDA Forest Service, is initiating a multi-city, long-term forest management study in the northeastern United States. This project continues the well-established tradition of long-term forest studies in the national forest system and private forests, which serve as demonstrations and test-beds for operational activities, such as the Hubbard Brook Experimental Forest or Bartlett Experimental Forest.[25] It is this type of knowledge that Olmsted hoped to advance in his call for applied research in Central Park, recognizing the need to establish new guidelines tailored to the urban landscape, in order to assure the long-term sustainability of these forests.


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CHRISTOPHER WOODALL

Figure 5 Left: A forest gap dominated by invasive vines in Pelham Bay Park, New York City. Right: Gap creation at Dartmouth Woods Adaptative Silviculture for Climate Change (ASCC) study site.

Traditional silviculture mimics disturbance events to create site conditions that will facilitate the establishment of select tree species and community types, but such approaches may not be available in cities, where canopy gaps are often rapidly taken over by invasive plants that suppress future tree establishment. Adapted urban silviculture approaches strive to accelerate gap recovery and suppress invasion.

By formalizing urban silviculture as a systematic and evidence-based approach, a novel suite of design approaches can be imagined. In recent decades, a new generation of landscape projects have aspired to create dynamic and complex urban forest landscapes that allow for growth and change over time. These designed landscapes informally engage silviculture concepts and incorporate some emerging knowledge from urban ecological studies, but the lack of integration between the professions has typically prevented a more deliberate application of ecological concepts that might have expanded the design palette with even more dynamic landscape processes rooted in applied ecological or silvicultural approaches. For example, the landscape architecture firm Field Operations, in its design for the Fresh Kills landfill competition (Fig. 6), had suggested leveraging forest succession concepts in its design for 'thread' thicket plantings on the landfill's slopes, but never considered applied nucleation, which had been studied by Robinson and Handel on another part of the same landfill, as part of an expanded afforestation strategy for the landfill. While consultation with applied restoration ecologists at BioHabitats resulted in a shift away from 'thread' thickets to a strategy of wider forested bands of 250-m width, the design did not benefit from experiments in applied nucleation going on nearby, which might have suggested the possibility of a larger-scale and more cost-effective afforestation method. (Construction is still ongoing, but at the moment no active afforestation outside of the applied nucleation experiments has taken place.) In another example, Brooklyn Bridge Park, a contemporary project by the landscape architecture firm Michael Van Valkenburgh Associates (MVVA), used what foresters would consider a nurse tree approach to quickly vegetate a post-industrial site and achieve the structural qualities of a forest. The designers planted an early successional plant community dominated by staghorn sumac, with small oaks and sassafras interplanted below; this dense planting shaded out undesirable invasive plants allowing the slower-growing oaks and sassafras to establish. The rhetoric of 'managed succession' in the design documents suggests that the designers embraced successional dynamics in their planting strategy, and statements about how the planting would be maintained in a state of arrested succession suggest an embrace of silvicultural techniques—although after construction the park managers took the landscape in a different direction (more akin to the classic designed forest park typology), favouring a denser and shadier condition, selecting for the later-successional oaks and sassafras rather than a more open meadow condition with early-successional sumacs, as had been the stated design intention,[26] so less arrested succession than 'accelerated' succession.

These designed forest plans were developed with some engagement with ecological consultants, but did not benefit as much as they could have from emerging ecological knowledge. Recent reforestation and afforestation studies testing the influence of soil amendments and early successional species as nurse trees are examples of emerging ecological knowledge, and these projects may have been better served by having science available that designers could access.[27] Conversely, these emerging approaches have not yet been fully tested, and designed landscapes such as these designed natural areas can help to inform the science—integrating experimental design into these public park projects could have helped to standardize and validate these novel afforestation methods.

As more projects at the forefront of this integration are designed and installed, both designers and ecologists stand to learn much by integrating methods of assessment and testing to track performance. Advances in applied urban ecology are beginning to provide such references, establishing novel strategies for more effective creation and maintenance of forests in cities, while also demonstrating why urban-adapted strategies may be necessary. As the science of urban forest ecology continues to expand, and the testing of operational measures continues to yield results, the toolkit of designers will continue to become better equipped to implement dynamic plans for managing forests in cities. Indeed, whereas Olmsted advised his colleagues to plant thick and thin quick, urban silviculture may inform practitioners just how thick to plant and how quickly to thin, among other management strategies, across different site types and forest conditions.

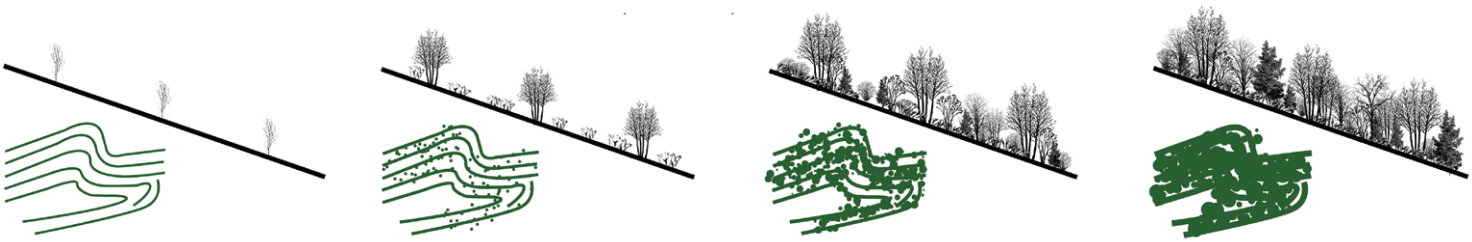

Figure 6 'Thread' thicket planting included in proposed phasing and development sequence from Lifescape competition entry for Freshkills Park, 2001.

NICHOLAS PEVZNER

Figure 7 Path at Brooklyn Bridge Park's Pier 1 through a dynamic managed woodland, showing off management activities and change over time.

The potential of design in urban silviculture

Just as science can inform designers in their quest to build better-performing designed landscapes, so too can design inform urban silviculture, reinvigorating the public perception of forests in cities and reinserting designers as decision makers in these landscapes. A major challenge for urban silviculture is the lack of public literacy regarding forest management, which is limited by land managers' ability to communicate intent and future outcomes. Whereas Olmsted lamented the public's misunderstanding of the need for active management to assure forest health and resilience, he may have missed the opportunity for design to take the lead in communicating these actions, educating the public and nurturing new perceptions of forest management. Design, with its tools for producing legibility in designed landscapes, offers techniques and approaches to overcome this literacy gap and improve the public legibility of urban forest management and its ecological dynamics.

In fact, the attribute of legibility is a key component of successful park designs.[28] Legibility can also extend to that park's ecological systems. Joan Iverson Nassauer highlighted the disconnect between public understanding of ecological function and expectations of neatness and order as formal signifiers of landscape performance. This disconnect requires a process of translation—from ecological patterns into cultural language, and the need 'to frame ecological function within a recognizable system of form'.[29]

Landscape architecture can use its skill at shaping public perceptions of landscapes to increase the acceptance of unfamiliar scenes and landscape qualities, including helping to acculturate the public to see active forest management as part of the park experience. In Brooklyn Bridge Park the establishment of a dense canopy of early successional sumac trees resulted in the need for the park's staff to intentionally cut back some sumacs to release oaks that had been interplanted below. Brooklyn Bridge Park introduced the public to non-traditional landscape qualities (early successional dense young forest), but it could have been a great opportunity to also invite the public to witness the activities and traces of tree removal (Fig. 7).

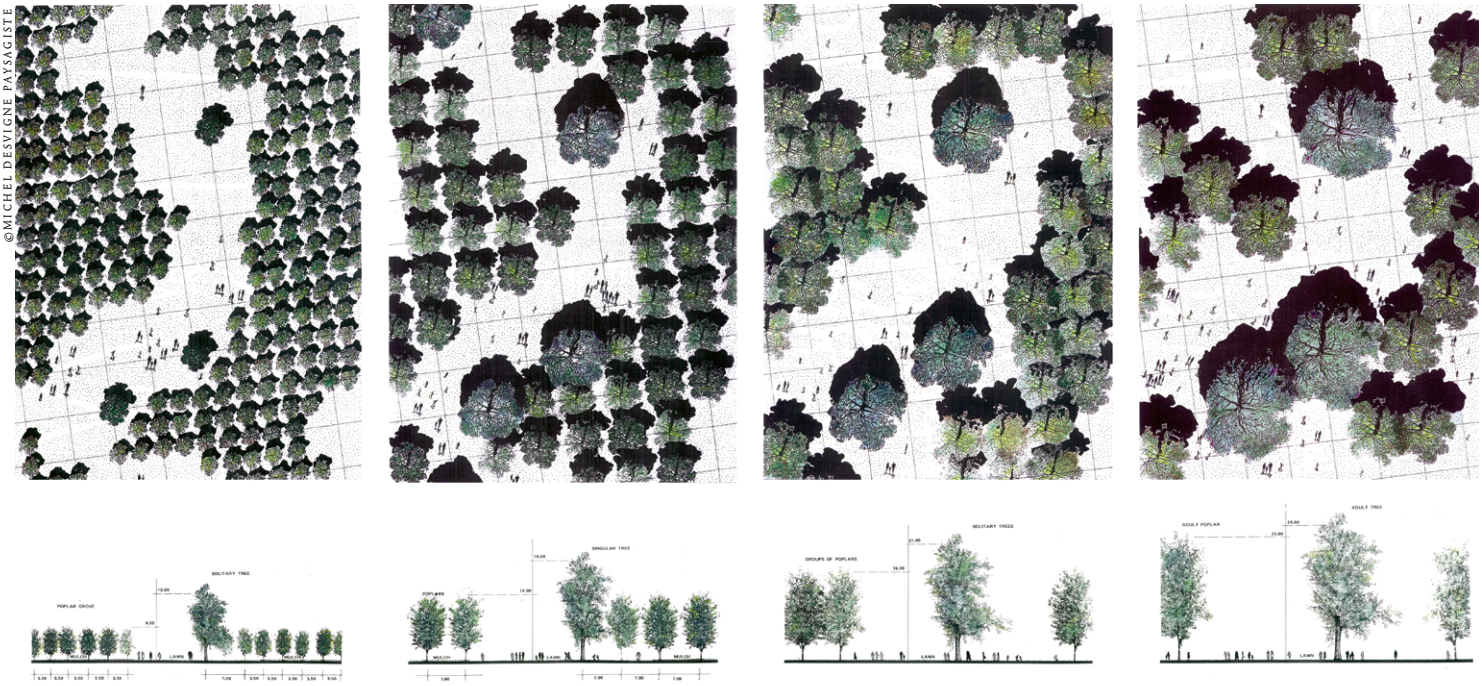

Figure 8 Millennium Park Greenwich forest development sequence by Michel Desvigne Paysagiste with Christine Dalnoky, 1997.

While the changing composition and structure of the forest and the presence of sumac stumps indicate a very active management regime, these clues are only visible to the trained eye. The non-traditional landscape qualities are not explicitly marked or highlighted, nor does a counterfactual forest exist nearby to be compared against. While the public is invited to enjoy the lush new landscape on a former industrial site, the ecological and silvicultural dynamics in this case are legible mostly to foresters and landscape professionals. Explicit informative signage or public events and tours around these management activities would make this dynamic silvicultural regime more legible to members of the public.

There are designed parks whose whole concept is based on silvicultural strategies. Landscape architecture firm Michel Desvigne Paysagiste's Millennium Park Greenwich (Fig. 8) prominently features a strategy of thinning. Conceptual drawings of the park design alert the public to the differences between the initial planted condition and the spatial qualities that would result after several thinning treatments. Both Millennium Park Greenwich and Desvigne's project for the riverfront in Bordeaux use uniform direct planting to quickly establish initial tree cover to help shift the site away from its legacy industrial character, with subsequent spatial definition coming from the retention and release of the hardiest trees through several rounds of tree removals.[30] While these projects might not take full advantage of the range of treatments that an urban silviculture offers, they do actively embrace the use of the 'axe' in the park's design and evolution.

Through the most subtle of interventions, design can transform spontaneous, often-abandoned forest landscapes into public amenities and places of leisure that welcome the public. The Natur-Park Schöneberger Südgelände in Berlin (Fig. 9), for example, was formerly an abandoned railyard, but was transformed into a public park through the preservation of its industrial relics and its spontaneous vegetation, as well as by the introduction of paths that traverse a series of multiple clearly delineated management regimes and forest stands.[31] The park design strikes a balance between providing access to the public and protecting areas of delicate habitat. In some parts of the park, visitors are welcome to move about freely and use the space for gatherings and other activities, while in others—particularly the dry grasslands being managed for biodiversity—the path lifts up from the ground as it traverses the area, subtlety directing visitors to stay on it. By implementing such spatial cues, designers can subtly guide and direct visitors, inviting certain activities to take place in specific locations—or not.

Design can also be deployed for the purposes of education and demonstration. The Landscape Laboratory in Alnarp, Sweden is one example of landscape architects deploying silviculture as both an educational device and for the purpose of experimenting with silvicultural treatments and outcomes—in an urban demonstration forest landscape that is open and inviting to the public. Situated on the edge of the Alnarp Park Arboretum at the Swedish University of Agricultural Sciences, with public walking trails accessible from the same main road that the campus is located on, this experimental forestry landscape mixes standard forestry plantings with silvicultural treatments and some artistic pruning interventions in a rich, varied and diverse set of spatial experiences.[32] Part art installation, part educational project, this landscape expands the vocabulary of what kind of spatial and emotional effects are possible with silviculture.

One of the more didactic types of landscape experiences is the interpretive trail, explicitly educational in its intent yet still a designed and curated landscape experience. Landscape architects are skilled at using the spatial structure of vegetation for the manipulation of visitors' emotional affect, which they do by stringing spatial sequences together along a path, altering the sequence, rhythm, proportion, repetition and juxta-

Figure 9 Visitor trails at Natur-Park Südgelände traverse multiple clearly delineated forest management regimes, with the path becoming elevated in ecologically sensitive areas to direct visitors to stay on the trail.

position of various spatial moments, including topography, tree density, vegetation type, constructed vista, or light and shade. The Alnarp Landscape Laboratory, for example, uses slight changes in its path geometries, like subtle bends in the trail and contrasts between the path running parallel to or diagonally intersecting geometrically planted areas, to supplement the spatial effects of the demonstration landscape. It moves visitors between dark, densely planted zones and geometrically shaped openings in the canopy, through intentional spatial effects that manipulate space and light through geometric plantings, pruning or tree removals—legibly human-made interventions that experiment with the spatial effects of different silvicultural moves. What if these kinds of spatial manipulations were combined with more explicit educational materials that could build public literacy of forest dynamics? By using spatial techniques to augment well-placed demonstration plots along a public path or trail, could designers not only raise awareness of specific silvicultural treatments, but also build ecological literacy against the counterfactual of an untreated forest (Fig. 10)? Perhaps by staging management activities as performative public events, as well as educational and participatory activities that involve the public, urban silviculture demonstration plots can help teach urban publics what a healthy and resilient forest should look like, and what kinds of management is required to keep it that way.

If forests in cities are to fulfil their role not only as ecologically important landscapes, but also as active social and cultural places, then the spatial and social expertise of designers may be important to incorporate into these landscapes' management. And for designers to expand their vocabulary of forest actions beyond the design and initial planting, and even beyond the vision of the 'mature' landscape, urban silviculture offers tools to better understand which longer-term trajectories of forest development are available, and to direct these forests' trajectories.

Conclusion

Forests in cities are complex socioecological assemblages, with not only flora and fauna to consider, but an enormous array of built infrastructure, people and communities, institutions and cultural systems. Something as simple as a neighbourhood park is enmeshed in systems of governance and maintenance, budgets and labour, social activities and cultural attitudes, desires and fears, aesthetic and lifestyle preferences. Despite its complexity and the diversity of stakeholders and stakeholder values, the urban landscape is a clearly artificial and manipulated construction—doesn't this make it the perfect testing ground to explore methods of implementing long-term, adaptive management? As Olmsted had long called for, forests in cities can be a living laboratory, from which methods of best practice may emerge. Urban silviculture provides a framework to systematically develop and deploy these approaches. Sustaining forests in cities, whether remnant mature forests or new plantings, will benefit from robust preparation for future threats such as pests, pathogens, fire, wind and climate change. For existing mature forests and new designed natural areas alike, it will be important to promote resilience and sustain forest cover, by accelerating forest establishment and promoting species and structural diversity. Future forest resilience and health depends on continued active management, perhaps even invasive action at times. This could entail techniques that are rarely used in cities today—including selective thinning, along with a suite of emerging evidence-based, urban-adapted treatments that challenge some of today's public expectations and forest management policies.

In established mature forests, whether old large parks or remnant forests that lack species and age diversity, we can hedge our bets and make opportunities for dynamism, so that inevitable disturbances may be readily replaced by new growth and populated by species adapted to future conditions. In designing new and future forests, whether urban afforestation projects or designed natural areas, active forest management could

Figure 10 Proposal for demonstration urban forests, featuring educational trails with interpretive signage making legible various silvicultural treatments against the backdrop of untreated forest, and interpreting the resulting ecological dynamics for the visiting public.

be integrated into visitors' experience, so that the public comes to understand what an ecologically healthy, resilient and climate-adapted forest looks like. A well-informed public that understands forest dynamics, the value of selective thinning, of making space in mature older forests for resilient and climate-adapted younger stands, might be a better steward and advocate for sustaining urban greening initiatives beyond the initial planting campaign.

What new interdisciplinary approaches must we develop to get us closer to an urban silviculture? For landscape architecture, this might entail even more of an embrace of contemporary ecological science and land management, certainly beyond the horticultural approach that is still all too common in many programmes. What if training included interdisciplinary workshops on what the initial planting and subsequent interventions might yield twenty, forty or a hundred years after planting? For landscape architecture offices engaged in municipal work that includes forests in cities, could an urban silvicultural approach include an insistence on involvement of the ultimate managers, or better yet, a long-term contract that allows for ongoing involvement in management decision making? For forest managers, what if the social perception of on the ground work was more actively considered? Forest managers already think in ten, twenty and one hundred-year timescales, but the programming tends to be purely ecological. How do we actively make that programming more dynamic, more socioecologically integrated? An urban silvicultural landscape approach could innovate interdisciplinary approaches for reinstating social programming into ecological forest management.

In moving beyond the axe, today's urban forests demand a spatially aware and ecologically sophisticated evidence-based approach to urban silviculture that is responsive to the complexity of cities' social and ecological dynamics. The emerging urban silvicultural landscape can be a dynamic one, where visitors understand the forest management that they might see as a kind of ongoing design practice, a spatial choreography that they can revisit and see develop over time. Visitors might come to see the forest not simply as a passive green space or a simple escape from the noises and hard surfaces of the built environment, but rather one where they understand their connection to this landscape's past and future health—where trees of the present day are legible in the context of past actions that have shaped the forest over time—and in the context of their future selves, the antecedents of the future forest, with contemporary actions clearly linked to future outcomes. In this way, the public can move from being passive consumers of visual experience in landscape, towards active participants in a collective activity of landscape stewardship.

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