Title
Conceptualizing social-ecological drivers of change in urban forest patches

Journal
Urban Ecosystems, 24(4)

ISSN
1083-8155

Authors
Johnson, Lea R
Johnson, Michelle L
Aronson, Myla FJ
et al.

Publication Date
2021-08-01

DOI
10.1007/s11252-020-00977-5

Peer reviewed

Urban Ecosystems
https://doi.org/10.1007/s11252-020-00977-5

Conceptualizing social-ecological drivers of change in urban forest patches

Lea R. Johnson[1,2] · Michelle L. Johnson[3] · Myla F. J. Aronson[4] · Lindsay K. Campbell[3] · Megan E. Carr[2] · Mysha Clarke[5] · Vincent D'Amico[6] · Lindsay Darling[7] · Tedward Erker[8] · Robert T. Fahey[9] · Kristen L. King[10] · Katherine Lautar[11] · Dexter H. Locke[12,13] · Anita T. Morzillo[9] · Stephanie Pincetl[14] · Luke Rhodes[15] · John Paul Schmit[16] · Lydia Scott[7] · Nancy F. Sonti[12]

Abstract

We introduce a conceptual model of the urban forest patch as a complex social-ecological system, incorporating cross-scale interactions. We developed this model through an interdisciplinary process engaging social and ecological scientists and urban land management decision makers, with a focus on temperate forest social-ecological systems. In this paper, we place the production and management of urban forest patches in historical perspective, present a conceptual model of urban forest patches within a broader regional context, and identify a series of research questions to highlight future directions for research on urban forest patches. This conceptual model identifies how spatial and temporal social-ecological drivers interact with patch-level conditions at multiple scales. Our integrative approach can provide insights into the role of social-ecological drivers in shaping forest health, biodiversity, and benefits forest patches provide to people in urban and urbanizing regions, with direct implications for decision-making to improve management outcomes.

Keywords Urban woodland · Social-ecological system · Drivers of change · Urban landscape · Interdisciplinary research · Conceptual model

Lea R. Johnson and Michelle L. Johnson have equally shared first authorship of this paper; other authors are presented alphabetically.

✉ Lea R. Johnson
ljohnson@longwoodgardens.org

1 Longwood Gardens, Division of Research and Conservation, Land Stewardship and Ecology Program, Kennett Square, PA 19348, USA

2 College of Agriculture and Natural Resources, Department of Plant Science and Landscape Architecture, University of Maryland, College Park, MD 20742, USA

3 USDA Forest Service, Northern Research Station, NYC Urban Field Station, 431 Walter Reed Road, Bayside, NY 11359, USA

4 Department of Ecology, Evolution and Natural Resources, Rutgers, The State University of New Jersey, New Brunswick, NJ 08901, USA

5 School of Forest Resources and Conservation, University of Florida, Gainesville, FL 32603, USA

6 USDA Forest Service, Northern Research Station, Philadelphia Field Station, 531 S College Ave, Newark, DE 19716, USA

7 The Morton Arboretum, Chicago Region Trees Initiative, Lisle, IL 60532, USA

8 Department of Forest and Wildlife Ecology, University of Wisconsin, Madison, 1630 Linden Drive, Madison, WI 53706, USA

9 Department of Natural Resources and the Environment, Center for Environmental Sciences and Engineering, University of Connecticut, 225 WB Young Building, 1376 Storrs Road, Storrs, CT 06269, USA

10 NYC Department of Parks and Recreation, Natural Resources Group, New York, NY, USA

11 Baltimore Green Space, 1212 N Wolfe St, Baltimore, MD 21213, USA

12 USDA Forest Service, Northern Research Station, Baltimore Field Station, 531 S College Ave, Newark, DE 19716, USA

13 National Socio-Environmental Synthesis Center, 1 Park Place, Annapolis, MD 01610, USA

14 UCLA Institute of the Environment and Sustainability, 619 Charles E. Young Drive East, LaKretz Hall Suite 300, Los Angeles, CA 90095, USA

15 Fairmount Park Conservancy, 1617 John F Kennedy Blvd #1670, Philadelphia, PA 19103, USA

16 US National Park Service, National Capital Region Inventory & Monitoring Network, Office of Natural Resources and Science, 4598 MacArthur Blvd. NW, Washington, DC 20007, USA

Published online: 12 July 2020

Introduction

Urban forest patches are a type of urban green infrastructure that can contribute to ecological functioning and sustainability in cities (Kowarik 2011; Elmqvist et al. 2015) and to residents' well-being (Tyrväinen et al. 2005; Berg et al. 2007; Korpela et al. 2010; Hauru et al. 2012; Song et al. 2016). At the same time, urban forest patches are subject to a variety of pressures, including increasing housing demand; deposition of atmospheric pollutants; spread of invasive species, pests, and pathogens; urban heat island effects; and isolation effects on recruitment and dispersal (Alberti 2005; Pouyat et al. 2007). Many urban restoration and afforestation projects are being implemented as a result of growing awareness about the benefits of urban forest patches (e.g., City of Seattle Parks and Recreation 2011; Bounds et al. 2015; Rink and Arndt 2016; Sanesi et al. 2017), and the potential of urban land to conserve local biodiversity and provide habitat for rare plants is also increasingly clear (Schwartz et al. 2002; Rebelo et al. 2011; Kantsa et al. 2013; Soanes et al. 2019). Conceptualizing these forests as a social-ecological system (Vogt et al. 2015) and integrating systems thinking into land management decision-making are key for long-term efforts to promote health, sustainability, and conservation of these important habitats.

The term *urban forest* is often understood to encompass all trees in a metropolitan region, including trees on private and public lands, individual street and yard trees, parks, and wooded areas (Nowak et al. 2001; Roman et al. 2018). Urban forest patches, also referred to as urban woodlands (Konijnendijk 2003), are a key dynamic component of the urban forest in regions where forests are a dominant local vegetation type, as in cities situated in temperate and tropical ecoregions. Urban forest patches may also make up a large proportion of the overall wooded habitat in some metropolitan areas, and can be hotspots of biodiversity (Kowarik and Körner 2005; Müller et al. 2018; Pregitzer et al. 2018), harboring native species that are often poorly represented in other components in the urban forest (Fahey and Casali 2017) while providing important outdoor recreational and educational experiences for people living nearby (Miller 2005; Soga and Gaston 2016).

Both social and ecological aspects of urban regions affect the ecological conditions of urban forest patches and their long-term potential to provide social and environmental benefits (Ogden et al. 2019). However, further work is needed to understand urban forest patches as complex multi-scale social-ecological systems to support decision-making and improve outcomes of management actions. In this paper, we introduce a conceptual model of urban forest patches as urban social-ecological systems in temperate forested regions. After first defining urban forest patches (UFPs), we place the production and management of urban forest patches in historical context and consider how they have been viewed through different disciplinary lenses. We then present our conceptual model of UFPs as a social-ecological system within a broader region to elucidate how multi-scale social-ecological drivers affect patch-level conditions and how forest conditions may in turn influence social-economic and cultural processes. Subsequently, we consider how forest conditions and change trajectories can affect benefits and disservices that urban residents accrue from these patches across spatial and temporal scales. We close by highlighting future directions for research on UFPs, with direct implications for urban and urbanizing areas situated in diverse types of forested ecoregions worldwide.

What is an urban forest patch?

We define an urban forest patch as a place where forest vegetation is spontaneously regenerating and predominantly self-organizing, located in a matrix of urban land uses, such as the built environment (Fig. 1). We consider urban forest patches to be assemblages co-produced by humans, biota (e.g., plants, animals), and abiotic components that interact as a social-ecological system. This definition draws on assemblage approaches in the social sciences, which acknowledge that plants and animals are active agents in this system, or 'actants', rather than considering them only as material substrates upon which humans act (Latour 2005; Bennett 2010). Prior work in this tradition has examined vegetation—such as trees, grass, and wetland plants—as actants with which humans interact in forming assemblages that vary in their physical form and management approaches, including gardens (Power 2005), lawns (Robbins 2012), and tree-lined streets (Perkins 2007).

An urban forest patch is a dynamic system that exchanges species, materials, and energy with the surrounding landscape: plant litter and seeds fall on its soils, trees and other forest plants disperse, germinate, grow, and reproduce within its boundaries and may also spread outside the patch. Human actions play direct and indirect roles in the existence, persistence, and condition of such patches. Urban forest patches support ecological processes and functional complexity relative to their surroundings. An urban forest patch does not include street, yard, and landscaped park trees – beneath which regeneration is discouraged through direct management practices – although nearby trees in these contexts may deposit seeds into a forest patch. Our definition includes both wild woodlands as defined by Kowarik and Körner (2005) and Konijnendijk (2005) as well as forests of diverse cultural origins originally planted by people, and aligns with the broad definition of a natural area forest applied by Pregitzer et al. (2019) to suggest the need for collective, rather than individual tree management.

Urban forest patches may be located anywhere in an urbanized region where trees grow spontaneously when the land is not actively managed or in places deliberately managed to

Fig. 1 Defining the urban forest patch

An urban forest patch:

- Is an assemblage co-produced by interactions of humans, other biota (i.e., plants, wildlife), and abiotic components as a social-ecological system
- Is a place where trees grow spontaneously when the land is not managed by people (e.g., not a desert)
- Has spontaneously regenerating and predominantly self-organizing forest vegetation
- Is a dynamic system located in a matrix of urban and other land uses, with flows of energy, species, and materials connecting with the surrounding landscape
- Is a place where plant litter and seeds fall on the soil, and trees and other forest plants disperse, germinate, grow, and reproduce
- Is a system that supports ecological processes and functional complexity
- May follow multiple trajectories of vegetation dynamics or succession following disturbance
- May contain native biota characteristic of regional forests, ecotypes, and biomes, as well as species introduced intentionally and unintentionally
- Can be found across different ownerships and boundaries
- May be subject to varied management actions and uses
- May have diverse land use histories and surrounding landscape contexts

maintain forest cover. UFPs have diverse land use histories, surrounding land uses, sizes, ownership patterns, present-day management, visitor use patterns, and contributions to people's quality of life. For example, they may be remnants of an old forest that was never cut, part of a former fuel woodlot, or represent regrowth on land that was once deforested. They may arise spontaneously on abandoned land or be initiated by afforestation or reclamation. They can be found on public or private property, or crossing ownership boundaries, and where management is active or passive. UFPs may contain multiple stages of vegetation development or succession and may follow multiple trajectories of vegetation dynamics. These plant communities are a result of complex land use (such as historical and successional trajectories including periods of agricultural use or urban development and subsequent abandonment). Over time, native species have persisted or been extirpated, and other species (such as agricultural crops, weeds, ornamental plants, pests, pathogens, and pets) have been introduced by changing land uses and preferences over time.

The need for a social-ecological systems approach

Complexity in urban systems creates a challenge for characterizing and understanding the roles of social and ecological drivers of change (Band et al. 2005). Considering UFPs within a social-ecological systems framework allows identification of drivers and interaction effects that may not be readily apparent using a single disciplinary approach. To this end, we have developed a conceptual model of drivers of change in UFP condition. This model can be used to form hypotheses and identify gaps in knowledge about such drivers, about how UFPs function, and about the role they play in larger urban systems. Below, we present ways to consider UFPs as a social-ecological system (Vogt et al. 2015) from multiple perspectives.

Historical consideration of urban forest patches

The existence of forest patches in cities has been both the result of deliberate planning and of neglect (Konijnendijk 2005). Urban forest patches result from many historical processes; they may be remnants of commonly held land, former estates or hunting grounds (Lawrence 1997), places unsuitable for building, abandoned land, or spiritual sites (Ignatieva et al. 2011). Forests patches have been incorporated in many public parks designed to provide escape and clean air in crowded cities. The idea that trees should be a part of landscapes, and in cities – whether they had historically grown in that landscape – has become a value embedded in city development (Lawrence 1993).

How forests patches in cities have been conceptualized in the United States, where our research team is located and derives much of our collective cultural knowledge from, has shifted over time as urbanization and land use development patterns have changed the nature and character of cities and their surrounding regions. Many city parks and vegetated public open spaces were initially planned with the advent of industrialization. Accelerated urban population growth and crowded conditions for the industrial working class led leading landscape architects and planners to advocate for parks in the 1850s. Park design was dominated by an English pastoral aesthetic, with forest patches and large lawns for picnicking and family activities. This sensibility became normalized in park and open space creation across the U.S., with forest patches often a deliberate part of park design (Cranz 1982).

In the U.S., the advent of zoning laws in the 1920s separated land uses and created limitations on development of forest lands. After World War II, suburbanization also brought shifts in aesthetics, social norms, and subsequent use of greenspaces in metropolitan regions (Jackson 1987), creating private and public greenspaces, both manicured and "natural", while highways and other development activities created difficult-to-access isolated forest patches. In the midtwentieth century, the growing technical platforms of urban planning and management began to be applied to UFPs, both public and private. Today, the rise of interest in ecosystem services provided by nature in the city has influenced the approach toward open space planning (Lovell and Taylor 2013; Ahern et al. 2014), following on the development of the Millennium Ecosystem Assessment that put forth both the value of, and definitions for ecosystem services (MEA 2005). Also, recent decades have seen a shift towards systems thinking in management and balancing social and ecological factors in decision-making (Folke et al. 2010).

Ecology in and of urban forest patches

Urban forest patches have served as an important laboratory in the development of the interdisciplinary science of urban ecology at multiple scales and across emerging disciplines.

Early records of the plant communities of UFPs come from descriptions of urban flora and natural history collections. Floras (i.e., species lists) for urban areas were first recorded in the middle ages in Europe; detailed descriptions of the plant composition of urban green spaces include Johnson's 1629 list of species occurring in London's Hampstead Heath, a park including a remnant forest patch (Sukopp 2008b). However, it was not until the 1970s that systematic mapping and analysis of urban vegetation began to occur, following a period of observation of the development of plant communities on rubble after World War II (Sukopp 2008a). Systematic approaches to community ecology began to be applied in cities, and in particular to urban green spaces, including forest patches (e.g., Rogers and Rowntree 1988; Loeb 1989, 1992) as urban forest patches began to be considered an ecological phenomenon deserving of study (Airola and Buchholz 1984; Dorney et al. 1984; McBride and Jacobs 1986; Sharpe et al. 1986; Kowarik and Körner 2005).

The urban-rural gradient approach was established using forest patches as a study system to understand how cities affect the environment more broadly (McDonnell and Pickett 1990), yielding important insights into urban biogeochemistry (Pouyat et al. 2009). The urban-rural gradient approach has since contributed to the understanding of how several taxa respond to urbanization – particularly birds, plants, and insects – and has drawn attention to the need for a multivariate approach to understanding gradients of urbanization (McDonnell and Hahs 2008).

Ecological studies focused on forest patches have since contributed greatly to our of understanding of ecology in and of cities, including ecological succession in urban contexts (e.g., Doroski et al. 2018), habitat values and species use of urban ecosystems (e.g., Lehvävirta et al. 2006; Handley et al. 2015), and food webs and trophic structures in urban ecosystems (e.g., McCary et al. 2018). Urban forest patches can have higher species richness than the surrounding landscape (Alvey 2006), and harbor rare native species (Kowarik 2011).

Insights gained from urban forest patches at the landscape scale (Wu 2014) have contributed to an increased understanding of plant functional groups and forest edges in cities (Godefroid and Koedam 2003a) and biodiversity conservation (Sukopp and Weiler 1988; Löfvenhaft et al. 2002; Godefroid and Koedam 2003b). Others have examined patterns of change in forest patch size, shape, and number (Zipperer et al. 2012), and have emphasized the importance of the urban landscape matrix to native and non-native species dispersal (Lopez et al. 2018). Recent city or metropolitan region-wide approaches have yielded new insights such as indicating that land cover, land use histories, and pre-urban vegetation have lasting effects on ecosystem structure and function (e.g., Fahey et al. 2012; Carter et al. 2015; Fahey and Casali 2017).

Restoration ecology studies of urban forest patches have improved understanding of restoration options and outcomes in urban ecosystems, often focusing on management of invasive non-native plant species. Urban environments are sites of frequent plant introductions and can be a source of invasive plants to the surrounding landscape (von der Lippe and Kowarik 2008), and invasive plants are a common focus of UFP management focused on biodiversity conservation and restoration. Studies have found that ecological restoration can have long-term effects in UFPs (Johnson and Handel 2016) and have emphasized the importance of 1) planting following invasive plant removal (Simmons et al. 2016) and of 2) management consistency and intensity over time (Johnson and Handel 2019) for efforts to increase biodiversity in UFPs dominated by invasive plants. The challenges of management for biodiversity in the urban context have led to new approaches to site evaluation and reference sites (Ehrenfeld 2000), and to afforestation on extremely altered sites (Robinson and Handel 2000). Studies of plant recruitment and community composition in urban forest patches have revealed limitations in both species movement and site conditions suitable for tree regeneration related to altered soil conditions (Kostel-Hughes et al. 1998), predators, and competition (Beauchamp et al. 2013; Labatore et al. 2017). Others have revealed effects of trampling and proximity to urban land uses on community composition (Matlack 1993; Lehvävirta et al. 2006; Malmivaara-Lämsä et al. 2008; Hamberg et al. 2009, 2010). These insights are important for developing approaches to urban forest patch management.

Management and stewardship of urban forest patches

Urban forest patches exist in a highly heterogeneous landscape mosaic that is managed and stewarded by a diverse array of public and private landowners and land managers (Svendsen and Campbell 2008). Together, these individuals and organizations comprise the multi-scalar governance network that influences environmental actions and outcomes affecting urban forest patches; this governance network includes actors in the government, business and civic sectors (Lemos and Agrawal 2006). Direct and indirect actions stemming from management and stewardship objectives, policies, and decision-making affect the structure and composition of individual patches and networks of UFPs. However, management and stewardship actions are often constrained by municipal or other finances. Public lands are managed by agencies at federal, state, county, township, and municipal levels for a range of functions from landscape conservation to preserving water quality and providing recreation opportunities. While property ownership is a key influence on land use and management practices (Aronson et al. 2017), there are also important examples of stewardship, or caretaking, by land managers who do not directly own a parcel. Such stewardship practices can occur both through formal arrangements or agreements and more informally on a voluntary, ad hoc basis. Hybrid governance of UFPs can take the form of shared stewardship, or public-private partnerships that leverage the different expertise of multiple sectors (e.g. MillionTreesNYC campaign (Campbell 2017). Participation in environmental stewardship activities may allow for a greater appreciation and use of UFPs (Fisher et al. 2015; Sonti et al. 2020).

The distribution, condition, and composition of vegetation communities in UFPs can vary by land ownership and sociodemographics of neighboring communities. Management actions on private lands are directed by landowners but can also be guided by local, state, and federal regulations and incentives (Quartuch and Beckley 2014). As examples of exurban and suburban private land decision-making, adoption of conservation easements in Iowa, Illinois, Michigan, Ohio, and Wisconsin was most influenced by place attachment (Farmer et al. 2011), and homeowner associations often restrict or prescribe land management activity at fine scales (Lerman et al. 2012). Limited research has focused on urban forest patch management by private landowners; more is known about public management in cities.

On public lands, management actions are also affected by governance structure and rules, including the actions of civil society as stewards. When considering an urbanized region, variations in management across municipalities can affect UFPs, as coordination among municipalities is voluntary rather than mandatory. UFPs may be included in urban forest management plans, which an increasing number of municipalities are creating (Ordóñez and Duinker 2013).

Application of silvicultural practices to UFPs to address a wide variety of socio-ecological goals has become more common in recent decades (Duinker et al. 2017). This expanded activity has stemmed from a variety of sources including application of European “close-to-nature forestry” or North American “ecological forestry” (Toni and Duinker 2015), silvicultural restoration based in an ecological restoration framework (discussed above), and urban forest design based in landscape architecture and urban design principles (Konijnendijk et al. 2006). Recent interest in reforestation and afforestation has yielded new insights and has been equally grounded in ecological restoration and traditional forestry frameworks (Robinson and Handel 2000; Oldfield et al. 2013; Pregitzer et al. 2016). Across many areas there is new (or renewed) interest in the potential for urban forests to produce both timber and non-timber products in addition to their provisioning of ecosystem services and social benefits (Brashaw et al. 2012; Cassens and Makra 2014; Urban Wood Network 2017).

Social uses and benefits of urban forest patches

Urban forest patches can provide benefits to people whether they are visiting a patch, viewing a patch from surrounding lands, or located where benefits can be received. Benefits of UFPs to the surrounding community include reducing the urban heat island effect (Douglas 2012), food provisioning (McLain et al. 2014), and supporting services, such as providing habitat for wildlife (Kang et al. 2015; Lepczyk et al. 2017b). Urban forest patches also provide various cultural services, as they provide space for nature recreation, create a sense of place and shared community, and help to maintain cultural heritage (Sonti et al. 2020; Frank et al. 2006). How people use and benefit from UFPs can vary by landscape position, accessibility, ownership, and the forest’s structure and condition (Coles and Bussey 2000; Carrus et al. 2013; Campbell et al. 2016; Ode Sang et al. 2016; Song et al. 2016). For example, forest vegetation may be perceived as a nuisance or even threatening, depending on social context, gender, individual preference, and vegetation characteristics (Burgess 1996; Heynen et al. 2006; Brownlow 2006; Jansson et al. 2013). Urban forest patches can also have educational benefits; some have been used as the grounds for long-term studies using successive cohorts of university students over decades. Such sites not only afford opportunities for teaching field techniques; they may also exemplify the value of monitoring, continuity, and restoration (Turner et al. 2007; Hopfensperger et al. 2011; Ladin et al. 2016).

Use and meaning

Much research on UFPs is conducted within publicly owned parkland. Less research has occurred in private land uses and “informal urban green space”, which includes vacant lots, brownfields and transportation corridors (Rupprecht and Byrne 2014). Relationships among visitation and ecological condition or vegetation structure of forests are complex, and more research is needed to understand how interactions among size, ownership, management and ecological condition of urban forest patches may affect visitation amount and quality. People visit UFPs for many reasons, including outdoor recreation, socializing, experiencing nature, and seeking refuge (Campbell et al. 2016; Ostoić et al. 2017), yet the influence of UFP condition on these motivations is unclear. In an examination of motivations for park use and ecological condition of public UFPs in New York City, Johnson et al. (2018) found mixed relationships between ecological condition and measures of 1) visitor activity and 2) use motivations, suggesting the potential for other factors to affect these relationships. Visitor activity was positively linked with structural aspects of an ecological threat index (e.g., presence of invasive species), while at the same time sociability and enjoyment motivations were positively linked with structural aspects of an ecological health index (e.g., presence of complex structure, presence of native species).

Use of UFPs can be facilitated and limited by a number of social and ecological factors. For example, although women can experience equal or greater benefits from their time spent in nature, they are also likely to feel less safe than men in urban forest patches, limiting their access to these benefits (Virden and Walker 1999; Jorgensen et al. 2002; Ode Sang et al. 2016; Sonti et al. 2020). Black women in particular may fear violence in urban green spaces including forest patches (Taylor 1993; Brownlow 2006). Race and ethnicity can impact the preferences and lived experiences of park visitors in urban and rural contexts (Elmendorf et al. 2005; Byrne and Wolch 2009; Finney 2014), but what explains broader patterns of preferences, use, and meaning of UFPs across racial and ethnic identities is not known. Place attachment to urban forested parks can also vary by one's relationship with place; Ryan (2005) found that neighbors and visitors to hold place-specific attachment to an urban park, while volunteers, staff, and people with extensive natural-areas knowledge held more of a conceptual attachment. These factors have implications for the care and stewardship of UFPs, as place attachment has been shown to facilitate pro-environmental behaviors in park visitors (Halpenny 2010).

At the same time, visitors can negatively affect the forest condition of UFPs via actions such as trampling, introduction of invasive species, waste dumping, and firewood gathering (Matlack 1993; Lehvävirta et al. 2006). Although studies show that visitors use UFPs as foraging locations (McLain et al. 2014), urban planning and policy still struggle to legitimize foraging as an appropriate recreational use of urban forests, including UFPs (Shackleton et al. 2017).

A conceptual model of urban forest patches

In November 2018, a group of social and ecological researchers and urban land management practitioners convened at the National Social-Environmental Synthesis Center (SESYNC) in Annapolis, MD (Palmer et al. 2016), to examine social and ecological drivers of change in UFPs. Expertise of the group included human and physical geography; urban, plant community, restoration, and ecosystem ecology; community organizing and non-profit administration; public land management; sociology; human dimensions of natural resources management; landscape ecology; and remote sensing and spatial analysis. During this meeting and subsequent iterations, we developed a conceptual model for understanding socio-ecological dimensions of urban forest patches. This model represents how our team of researchers and managers perceives change in urban forest patches in temperate-zone social-ecological systems, based on our shared expertise. The conceptual model is structured to show macro-scale and local drivers of change in UFPs, as well as other components of the local social-ecological system that can affect the ecological community of an urban forest patch (Fig. 2). We consider urban forest patches to be co-produced assemblages because of the interactions of humans, plants, animals, and abiotic components described above that interact to produce this social-ecological system.

Components of this co-produced urban forest assemblage, which can span metropolitan regions, include individual people, regional economies, multi-level governance networks, landscape configuration, forest patch conditions, and local biophysical drivers of forest change. Model components (boxes) and interactions (arrows) are described below and together with the diagram (Fig. 2) comprise our conceptual model. Arrows between component boxes highlight the actions of one component on another. For example, management and stewardship directly affect local biophysical conditions through actions such as removing trash and planting trees. We conceive of macro-scale social and biophysical drivers as having the potential to influence any or all components of the co-produced urban forest assemblage.

Model components

People

People interact with urban forest patches physically, emotionally, and politically at multiple scales. Forest visitors may experience environmental benefits and harms as a result of their encounter with an urban woodland, and can also influence site conditions through policy, stewardship, vandalism, use, or non-use. Adjacent neighbors and society at large experience indirect services and disservices related to the presence of a forest patch (Morzillo et al. 2016) and may advocate for policies or actions that cause development, conservation, or specific management practices with impacts related to the forest. In each case, individual and collective perceptions, values, experiences, and uses of the forest patch will shape

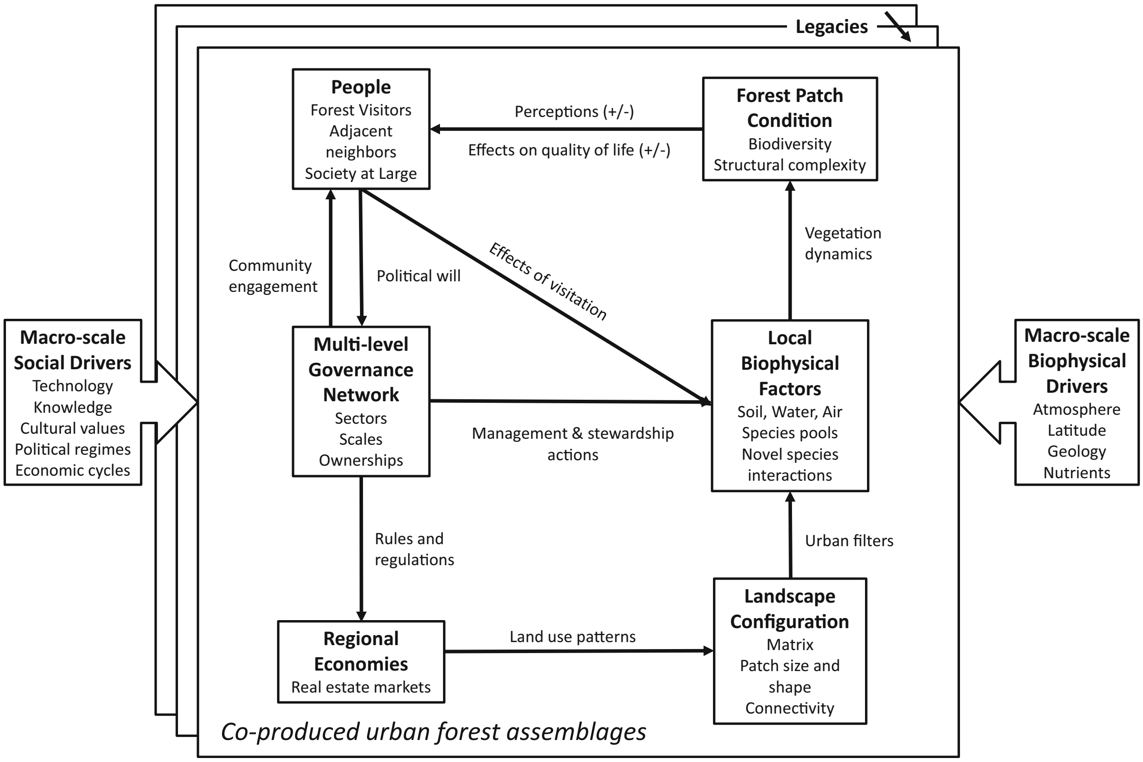

Fig. 2 A social-ecological conceptual model of urban forest patches. This transdisciplinary model was developed by a group including social and ecological scientists and urban land management decision-makers with a focus on temperate forested regions. Components of the model are illustrated by examples and described in more detail in the text

these interactions and outcomes (Morzillo et al. 2016; Campbell et al. 2016).

Multi-level governance network

In urban regions, forest management outcomes are the result of decisions made across diverse governance actors, at multiple scales and by multiple sectors (i.e., government, civic, business, public-private partnerships) (Svendsen and Campbell 2008; Lawrence et al. 2013; Buijs et al. 2016). Each governance entity is driven by individual sets of rules, organizational culture, mission, and objectives, group expertise/human capital, and available resources for decision-making and action. Organizations can range across scales of emphasis from a specific green space or location (e.g., Friends of Alley Pond Park) to a broader city or regional focus (e.g., Chicago Region Trees Initiative), with governance actions interacting at and across these scales. As a result, the scope of management decisions may be directed by international, national, or regional policy-making governance or rules (e.g., E.U. Biodiversity Strategy, US Fish and Wildlife Service policies and the Endangered Species Act), while other policies may be enacted based on or influenced by state or local ordinances or legislation. Governance actions can also be driven by non-governmental organizations focused on a particular resource (e.g., Arbor Day Foundation on trees) or recreational activity (e.g., bird watching). Spatial and temporal dynamics of governance may be further influenced by institutions focused on land use (e.g., land trusts). Regardless of scale and scope, results of decision-making among governance actors can influence local biophysical conditions and associated ecological drivers of forest change.

Regional economies

Many facets of regional economies have the potential to affect the co-produced urban forest assemblage, particularly land conversion and landscape configuration through real estate markets (Irwin and Geoghegan 2001; Ripplinger et al. 2017). Demands for housing, commercial space, transportation, and other needs mediated by real estate markets affect urban forest patches by changing land use over time. Such demands are regional in nature, crossing municipal lines, but are generally related to economic conditions of a metropolitan area such as job opportunities and broader macroeconomic shifts. Land development, or conversion of land to housing and commercial buildings, is determined by human preference, regulated by local policy, and is often tied to economic opportunity or perceived value to meet specific human needs. Property rights may be in alignment with these needs and desires, but, if not, may be overridden by planning agency goals resulting in a conflict in land use decisions. Factors influencing development include population growth, consumer values, trade, prices, housing unit production and the impact of macroeconomic factors. Land development patterns can be cyclical, reflecting real estate trends (Edelstein and Tsang 2007). These cycles of development and abandonment can lead to temporary opportunities for trees to grow and even time for an urban forest patch to mature. Similar patterns may also occur on public lands that are not currently utilized or left deliberately unmanaged. Urban greenspace, including UFPs, interacts with existing neighborhoods to affect property values (Saphores and Li 2012; Li and Saphores 2012).

Landscape configuration

Urban regions are characterized by a high degree of spatial heterogeneity (Pickett and Cadenasso 2009; Pickett et al. 2017) and are shaped by human-mediated changes that affect patterns of connectivity and isolation among habitat patches. Landscape ecology provides a theoretical framework to evaluate patch configuration (Forman 1995), revealing that how patches are configured on the landscape can affect site-level patch conditions (Dufour et al. 2006; Lepczyk et al. 2017a). For example, small forest patch size can increase abundance of woody vines that can suppress tree regeneration (Londré and Schnitzer 2006). Biophysical effects of proximity to forest edge, which can range from drying winds and increased light (Forman and Godron 1981) to trampling (Hamberg et al. 2009) and recreational activities (Matlack 1993), result in an increase in the importance of factors originating outside a forest patch to the regulation of ecological processes within it (Carreiro et al. 2009). Forest patches can also be evaluated in relationship to other similar patches by assessing patch configuration and connectivity affecting movement by species across heterogeneous urban land uses (Bender et al. 1998; Zipperer et al. 2012; Johnson and Munshi-South 2017). At broader scales, the matrix of other patch types that a patch is embedded within affects drivers of ecological change (McGarigal and Marks 1995; Driscoll et al. 2013).

Local biophysical factors

Plant communities are key to ecosystem processes. Plant primary productivity fuels food webs of other organisms, while the structure of plants themselves provides shelter, cover, and microclimates. Change over time in plant communities – also known as vegetation dynamics or ecological succession – is driven by local biophysical conditions: the availability of sites in which plants can grow, the pool of species available, and interactions between species (Pickett et al. 2011). In UFPs, these key drivers of change are shaped by the social and ecological context of cities. Biogeophysical conditions make sites available or unavailable for a plant species to germinate, grow, and reach maturity in a specific location. These conditions include space in which to grow, soils, moisture, nutrients, and light. In cities, urban heat island warming (Arnfield 2003), deposition of atmospheric pollutants (McDonnell et al. 1997; Zhu and Carreiro 2004), alteration of soils (Effland and Pouyat 1997), and invasive species (Piana et al. 2019) affect site availability, with implications for locally native biodiversity (Burghardt et al. 2009). The frequency, type, and intensity of ecological disturbances (White and Pickett 1985) occurring in cities are also shaped by urban land use transformations. These physical and temporal conditions make sites for establishment and growth more or less available to individual species, altering the composition and structure of forest communities.

Forest patch condition

The condition of an urban forest patch is an emergent property of local biophysical conditions, resulting from vegetation dynamics that are influenced by multiple social and ecological drivers. Forest patch condition can be understood as a multidimensional concept, including species composition, abundance, and diversity; the physical, biotic, and chemical properties of forest soils; age and regeneration of trees; and the physiognomy or physical structure of the layers of the forest, including herbaceous plants, shrubs, understory, and canopy. The ecological condition of an urban forest patch at a given point in time is a result of the interactions among historic and current actions by people (Fahey et al. 2012; Fahey and Casali 2017), governance networks (Cranz 1982; Sukopp 2008b), and local economic forces (Czech et al. 2000; Edelstein and Tsang 2007; Pickett et al. 2008; Essl et al. 2010; Gong et al. 2013) affecting landscape configuration and ecological drivers of vegetation dynamics. The biodiversity and structural complexity of UFP plant communities are important to their role in ecosystem processes, from primary productivity to nutrient cycling (Baxter et al. 2002; Imhoff et al. 2004; Ziska et al. 2004; Nagy et al. 2014).

Macro-scale social drivers

While our framework focuses on the regional scale, urban regions are open systems without spatial bounds and are influenced by flows from distant locations and other spatial extents (Heynen et al. 2006). Social drivers, such as changes in technology, knowledge, cultural values, political regimes, and economic cycles, occur at higher orders than a metropolitan region, but can affect how land use decisions and other governance actions occur within a region. Such drivers can have effects across a state, nation, continent, or the world, depending upon how flows of information, energy, capital, and resources are transmitted. With Internet connectivity, social shifts can occur rapidly and synchronously, as there is little time needed for transmission from one area to another.

Macro-scale biophysical drivers

Multiple biophysical drivers, such as air quality, climate, topography, latitude, and geology, can act on and interact with urban forest patch systems at larger scales. For example, climate effects are important at multiple scales, from local microclimates and urban heat islands, to regional and global patterns, with effects of global climate change affecting all of these scales. Latitude affects the extent of species' ranges, while geologic processes result in variation in soils and topography that affect which species and communities may be present in a given urban forest patch.

Legacies

All components and interactions in this social-ecological system are the result of processes and decisions that have unfolded over time. Past conditions of one component can affect one or more components; these effects are often non-linear (Roman et al. 2018).

Interactions among model components

Interactions among components of the model are indicated by arrows. All components of the model are interconnected, forming multiple loops. We represent arrows as one-way for representational simplicity, while recognizing many interactions may be bidirectional and often mediated by other components. This model seeks to explain interactions of its components by focusing on links and directions that are most relevant to forest patch condition.

Community engagement

Community engagement in governance can occur in a number of ways. Governmental agencies may solicit community input through meetings, voting, advisory bodies and other forms of outreach and process, often as part of required procedures of community notification and consultation. At the same time, governance actions, or lack thereof, can inspire or motivate the community to participate in advocacy for policies, programs, and resource allocation in response to actions perceived as negative or positive. Non-profit organizations, community groups, or individuals may also solicit community engagement through activities, events and opportunities to interact with sites and programs, building community interest or concern including investment of time and/or resources.

Political will

Political will is a term that can apply to organizations and individuals and is still being clearly defined in the literature (Kapoutsis et al. 2017). In this model, we use this term to refer to the support provided by the community that facilitates the intention or commitment of governance actors to enact management actions, policies, and/or laws. This support, or political will, can be created by the care the community has for the land, such as pro-environmental behaviors derived from attachment to place (Halpenny 2010).

Visitor effects

Forests in densely populated urban areas are more accessible and more frequently visited than suburban and rural forests under similar management regimes (Roovers et al. 2002; Arnberger 2006). People visiting an urban forest patch can have direct and indirect effects on the condition of urban forest patches. Direct effects can have negative effects on forest patch condition by altering species abundance or soil conditions, such as trampling of plants or soil compaction; or have positive effects through management efforts like planting or invasive species removal. Visitors can also have indirect effects, as when a behavior change due to visiting an urban forest patch results in changing regulations, management, zoning, or other governance affecting UFPs.

Management and stewardship actions

These actions are direct and indirect changes to an urban forest patch by intentional actors, including land managers, governing entities, community stewards, and volunteers. Common activities include trash removal; invasive plant removal; planting trees, shrubs, and herbaceous material; installation of signage and paths; clearing debris after storms; and soil amendment, as well as creating ordinances for conservation and protection.

Rules and regulations

Rules and regulations establish what government can and cannot do relative to city planning and management (Talen 2012). Ordinances and municipal code can affect the spatial distribution of land uses and also dictate how trees may be removed or planted on both public and private properties within a jurisdiction. Zoning is a type of regulation that allows and disallows certain activities and certain structures on a parcel. Through its ability to limit the available supply of land in a spatialized and specific way, zoning can influence property values, which in turn can affect supply/demand relationships elsewhere in the region. Zoning practices, including open space zoning, can be exclusionary, and create inequitable effects to residents of a city or town (Schmidt and Paulsen 2009).

Land use patterns

Land use refers to the many ways that people use and modify land. Land use differs from land cover in that it indicates which use people have for the land, which can affect its land cover category. For example, a forest patch can be present as forest (land cover) but ecological condition of the forest may differ because of different land uses (e.g., maintained as forest for timber production or conserved as forest to prevent built development on the parcel). Land use patterns can affect urban forest patches by affecting ecological drivers of forest change. For example, conversion of a vegetated area to a shopping center with a large parking lot can alter local biophysical conditions by increasing local temperature and changing the abundance and species composition of seeds deposited in a nearby patch (Robinson and Handel 2000).

Urban filters

The biodiversity of an urban forest patch is composed of a subset of species present in the region as a whole (Aronson et al. 2016). Together, urban biogeophysical conditions influenced by land use, land history, and landscape context exclude some species while others thrive, acting as filters on this regional species pool. Additional urban filters include urban form and history; the intentional and unintentional introduction of species – both plants and animals; and other human activities that influence species composition and dynamics, particularly management and use (Aronson et al. 2016, 2017).

Vegetation dynamics

The process of change over time in plant communities – vegetation dynamics, or ecological succession – is a result of interactions among physical site conditions, species pools, species interactions, plant-soil feedbacks, and disturbances (Pickett et al. 1987, 2011). In forested biomes, ecological disturbance is usually followed by the establishment of plant communities dominated by shade-intolerant forb and graminoid species; these communities transition over time to be dominated by longer-lived woody species, trees in particular. As forests mature, shade tolerant plants become dominant, particularly in the understory. In cities, vegetation dynamics are also shaped by the urban context. Successional trajectories are altered by urban site conditions and new disturbance dynamics, as well as management actions and species introductions (La Sorte et al. 2014), which can form novel assemblages (Kowarik 2011) and new patterns of interaction with no reference analog.

Effects on quality of life

The surrounding environment is one factor that can contribute to people's quality of life. Quality of life is a term initially developed in the health field, to conceptualize health as broader than physical health. Quality of life refers to overall life satisfaction and can be multidimensional, including overall community life satisfaction (Moons et al. 2006; Costanza et al. 2007) and social and economic wellbeing. Urban forest patches can make positive contributions to quality of life, as described above, including effects on physical and psychological well-being.

Perceptions of urban forest patches

Visitors and nearby residents can have both positive and negative perceptions of forest patches; these patches can provide wilderness experiences within the city (Sonti 2019, Sonti et al. 2020). Forest patch condition is known to influence such perceptions. Aesthetic appearance of forest structure is also known to influence perceptions, as in the case of forest density (Bjerke et al. 2006), which can vary by social and demographic factors (Shanahan et al. 2015). Effects of biodiversity (i.e., species composition) on perceptions of urban forest patches can also be influenced by other factors, including environment-related attitudes (Gunnarsson et al. 2017). Childhood nature experiences may also influence perceptions and use of urban forest patches (Thompson et al. 2007; Maruthaveeran and Konijnendijk 2014).

Questions the urban forest patch system allows us to explore

Urban forest patch assemblages are valuable systems for studying the interaction of social and ecological processes in human-dominated ecosystems. The discrete spatial and temporal context of a defined forest patch within a human-dominated landscape also allows for study of trajectories and cross-scale interactions (Fig. 3), such as 1) quantification of the composition and structure of the site-level vegetation community and 2) comparisons among patches of varying proximity and the broader characteristics of the landscape within varying distances from the patch. Similarly, the sociological context of the patch can be defined based on a variety of scales relevant to societal processes and actors and could even be used to evaluate the influence and importance of actors/actions at various scales (e.g., neighborhood stewardship vs. city-scale governance). The explicit spatial referencing of UFPs also makes it possible to place a patch and surrounding areas into a temporal context and take into account both the site-level history and changing broader local-to-regional context over time. Spatially and temporally referenced data describing discrete UFPs may also promote evaluation of

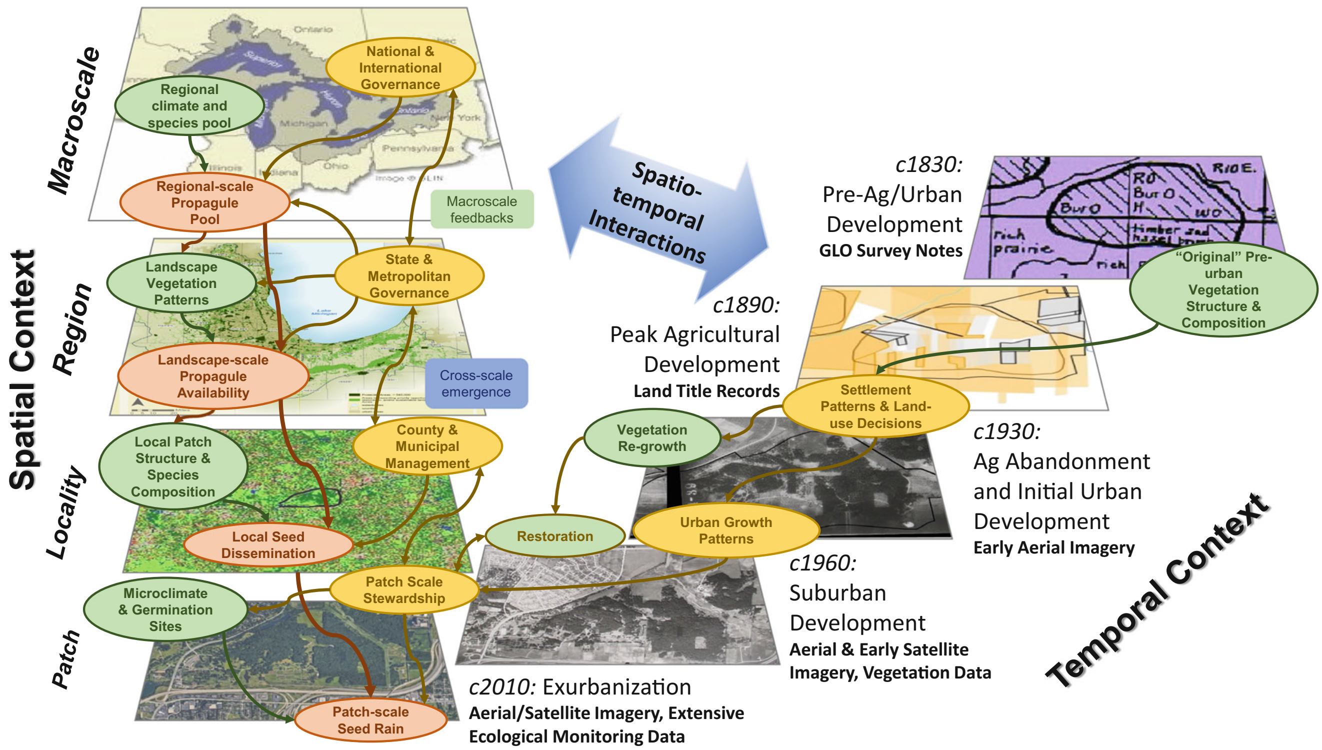

Fig. 3 Illustration of the temporal (moving through time from right to left) and spatial (moving from broader to finer scales from top to bottom) context of UFPs as considered most relevant to UFPs (i.e., not extending to continental/global spatial extent or evolutionary/geologic timescales). Specific example illustrates the spatio-temporal context of the "East Woods" of The Morton Arboretum in the suburban part of the Chicago metropolitan region and the relevant factors for assessing the socio-ecological system of urban forest patch propagule dynamics. For additional detail on the site and region see Fahey et al. (2012), Carter et al. (2015), and Fahey and Casali (2017)

feedbacks between social and ecological drivers of urban forest composition, structure, and function as well as changes in these relationships over time (e.g., investment/disinvestment in neighborhoods over time vs. city/regional governance and local-regional/continental/global-scale ecological drivers).

From the development of our urban forest patch conceptual model, we have identified a set of broad questions, which include:

- What are the different stewardship, management, and governance arrangements of urban forest patches?
- How do differing stewardship, management, and governance impact the condition of urban forest patches?
- How does the spatial distribution of forest patches relate to spatial and temporal patterns of land development?
- How do land use histories of urban forest patches relate to their current conditions, with respect to fauna and flora, species composition, condition, and distribution?
- Has increased societal awareness of the benefits of urban forest patches affected urban forest policies, funding, and management actions? If so, how?
- What types of interactions do individual people have with urban forest patches, and how frequent are those interactions?
- How do individual people value urban forest patches, and how do they contribute to people's quality of life?
- How will social and ecological dimensions of urban forest patches interact and change over time with changes in macro-scale drivers like technology, climate change, and changing social norms?

By conceptualizing social-ecological effects on the condition of urban forest patch assemblages within a metropolitan region, we have synthesized multi-scalar concepts from a set of social and ecological disciplines and areas of expertise, including human and physical geography; urban, plant community, restoration, landscape, and ecosystem ecology; community organizing and NGO administration; public land management; sociology; and human dimensions of natural resources. Our interdisciplinary conceptual model of urban forest patches as social-ecological systems with cross-scale interactions identifies questions about the patterns and processes of system components and their interactions. This urban forest patch model serves as a starting point from which to systematically examine these and other social-ecological questions about urban forest patches. We recognize that our model is a simplification of the system and anticipate that future empirical work may untangle complexity among and between individual components. For example, the multi-level governance network component is comprised of many actors, relationships, and scales. We have approached this effort with temperate forested regions in mind; as such, the model highlights opportunities for integrated social-ecological research on urban forests in those regions. With additions or modifications to model components and interactions, such as contextualizing local governance structures, rules and regulations, and ecological drivers of change, this model could be applied to other urbanized forested regions globally.

Acknowledgements This work was supported by the National Socio-Environmental Synthesis Center (SESYNC) under funding received from the National Science Foundation DBI-1052875.

References

Ahern J, Cilliers S, Niemelä J (2014) The concept of ecosystem services in adaptive urban planning and design: a framework for supporting innovation. Landsc Urban Plan 125:254–259. https://doi.org/10.1016/j.landurbplan.2014.01.020

Airola TM, Buchholz K (1984) Species structure and soil characteristics of five urban forest sites along the New Jersey palisades. Urban Ecol 8:149–164. https://doi.org/10.1016/0304-4009(84)90012-3

Alberti M (2005) The effects of urban patterns on ecosystem function. Int Reg Sci Rev 28:168–360

Alvey AA (2006) Promoting and preserving biodiversity in the urban forest. Urban For Urban Green 5:195–201. https://doi.org/10.1016/j.ufug.2006.09.003

Arnberger A (2006) Recreation use of urban forests: an inter-area comparison. Urban For Urban Green 4:135–144. https://doi.org/10.1016/j.ufug.2006.01.004

Arnfield AJ (2003) Two decades of urban climate research: a review of turbulence, exchanges of energy and water, and the urban heat island. Int J Climatol 23:1–26. https://doi.org/10.1002/joc.859

Aronson MF, Lepczyk CA, Evans KL et al (2017) Biodiversity in the city: key challenges for urban green space management. Front Ecol Environ 15:189–196. https://doi.org/10.1002/fee.1480

Aronson MFJ, Nilon CH, Lepczyk CA et al (2016) Hierarchical filters determine community assembly of urban species pools. Ecology 97: 2952–2963. https://doi.org/10.1002/ecy.1535

Band LE, Cadenasso ML, Grimmond CS et al (2005) Heterogeneity in Urban ecosystems: patterns and process. In: Lovett GM, Turner MG, Jones CG, Weathers KC (eds) Ecosystem function in heterogeneous landscapes. Springer New York, New York, pp 257–278

Baxter JW, Pickett STA, Dighton J, Carreiro MM (2002) Nitrogen and phosphorus availability in oak forest stands exposed to contrasting anthropogenic impacts. Soil Biol Biochem 34:623–633. https://doi.org/10.1016/S0038-0717(01)00224-3

Beauchamp VB, Ghuznavi N, Koontz SM, Roberts RP (2013) Edges, exotics and deer: the seed bank of a suburban secondary successional temperate deciduous forest. Appl Veg Sci 16:571–584. https://doi.org/10.1111/avsc.12036

Bender DJ, Contreras TA, Fahrig L (1998) Habitat loss and population decline: a meta-analysis of the patch size effect. Ecology 79:517–533. https://doi.org/10.1890/0012-9658(1998)079[0517:HLAPDA]2.0.CO;2

Bennett J (2010) Vibrant matter: a political ecology of things. Duke University Press, Durham

Berg AEVD, Hartig T, Staats H (2007) Preference for nature in urbanized societies: stress, restoration, and the pursuit of sustainability. J Soc Issues 63:79–96. https://doi.org/10.1111/j.1540-4560.2007.00497.x

Bjerke T, Østdahl T, Thrane C, Strumse E (2006) Vegetation density of urban parks and perceived appropriateness for recreation. Urban For Urban Green 5:35–44. https://doi.org/10.1016/j.ufug.2006.01.006

Bounds K, Feller MJ, Greenfeld J et al (2015) Guidelines for urban forest restoration. New York City Department of Parks and Recreation, Natural Resources Group, New York City, NY

Brashaw BK, Ross RJ, Wang X, Wiemann MC (2012) Wood utilization options for urban trees infested by invasive species. 96

Brownlow A (2006) An archaeology of fear and environmental change in Philadelphia. Geoforum 37:227–245. https://doi.org/10.1016/j.geoforum.2005.02.009

Buijs AE, Mattijssen TJ, Van der Jagt AP et al (2016) Active citizenship for urban green infrastructure: fostering the diversity and dynamics of citizen contributions through mosaic governance. Curr Opin Environ Sustain 22:1–6. https://doi.org/10.1016/j.cosust.2017.01.002

Burgess J (1996) Focusing on fear: the use of focus groups in a project for the community Forest unit, countryside commission. Area 28:130–135

Burghardt KT, Tallamy DW, Gregory Shriver W (2009) Impact of native plants on bird and butterfly biodiversity in suburban landscapes. Conserv Biol 23:219–224. https://doi.org/10.1111/j.1523-1739.2008.01076.x

Byrne J, Wolch J (2009) Nature, race, and parks: past research and future directions for geographic research. Prog Hum Geogr 33:743–765. https://doi.org/10.1177/0309132509103156

Campbell LK (2017) City of forests, city of farms: sustainability planning for New York City's nature. Cornell University Press

Campbell LK, Svendsen ES, Sonti NF, Johnson ML (2016) A social assessment of urban parkland: analyzing park use and meaning to inform management and resilience planning. Environ Sci Pol 62:34–44. https://doi.org/10.1016/j.envsci.2016.01.014

Carreiro MM, Pouyat RV, Tripler CE, Zhu W (2009) Carbon and nitrogen cycling in soils of remnant forests along urban-rural gradients: case studies in New York City and Louisville, Kentucky. In: McDonnell MJ, Hahs AK, Breuste JH (eds) Ecology of Cities and Towns, 1st edn. Cambridge University Press

Carrus G, Lafortezza R, Colangelo G et al (2013) Relations between naturalness and perceived restorativeness of different urban green spaces. Psyecology 4:227–244. https://doi.org/10.1174/217119713807749869

Carter DR, Fahey RT, Dreisilker K et al (2015) Assessing patterns of oak regeneration and C storage in relation to restoration-focused management, historical land use, and potential trade-offs. For Ecol Manag 343:53–62. https://doi.org/10.1016/j.foreco.2015.01.027

Cassens DL, Makra E (2014) Urban Wood and Traditional Wood: A Comparison of Properties and Uses. Department of Forestry and Natural Resources, Purdue University

City of Seattle Parks and Recreation (2011) Urban Forest Restoration Program. http://www.seattle.gov/parks/horticulture/forestrestoration.htm. Accessed 17 Apr 2013

Coles R, Bussey SC (2000) Urban forest landscapes in the UK — progressing the social agenda. Landsc Urban Plan 52:181–188. https://doi.org/10.1016/S0169-2046(00)00132-8

Costanza R, Fisher B, Ali S et al (2007) Quality of life: an approach integrating opportunities, human needs, and subjective well-being. Ecol Econ 61:267–276. https://doi.org/10.1016/j.ecolecon.2006.02.023

Cranz G (1982) The politics of park design. A history of urban parks in America. Massachusetts Institute of Technology (MIT) Press, London

Czech B, Krausman P, Devers P (2000) Economic associations among causes of species endangerment in the United States. BioScience 50: 593–1194

Dorney JR, Guntenspergen GR, Keough JR, Stearns F (1984) Composition and structure of an urban woody plant community. Urban Ecol 8:69–90. https://doi.org/10.1016/0304-4009(84)90007-X
Doroski DA, Felson AJ, Bradford MA et al (2018) Factors driving natural regeneration beneath a planted urban forest. Urban For Urban Green 29:238–247. https://doi.org/10.1016/j.ufug.2017.11.019
Douglas I (2012) Urban ecology and urban ecosystems: understanding the links to human health and well-being. Curr Opin Environ Sustain 4:385–392. https://doi.org/10.1016/j.cosust.2012.07.005
Driscoll DA, Banks SC, Barton PS et al (2013) Conceptual domain of the matrix in fragmented landscapes. Trends Ecol Evol 28:605–613. https://doi.org/10.1016/j.tree.2013.06.010
Dufour A, Gadallah F, Wagner HH et al (2006) Plant species richness and environmental heterogeneity in a mountain landscape: effects of variability and spatial configuration. Ecography 29:573–584. https://doi.org/10.1111/j.0906-7590.2006.04605.x
Duinker PN, Lehvävirta S, Nielsen AB et al (2017) Urban woodlands and their management. In: Routledge Handbook of Urban Forestry
Edelstein RH, Tsang D (2007) Dynamic residential housing cycles analysis. J Real Estate Finan Econ 35:295–313. https://doi.org/10.1007/s11146-007-9042-x
Effland WR, Pouyat RV (1997) The genesis, classification, and mapping of soils in urban areas. Urban Ecosystems 217–228
Ehrenfeld JG (2000) Evaluating wetlands within an urban context. Ecol Eng 15:253–265
Elmendorf WF, Willits FK, Sasidharan V (2005) Urban park and forest participation and landscape preference: a review of the relevant literature. J Arboric 31:311–317
Elmqvist T, Setälä H, Handel S et al (2015) Benefits of restoring ecosystem services in urban areas. Curr Opin Environ Sustain 14:101–108. https://doi.org/10.1016/j.cosust.2015.05.001
Essl F, Dullinger S, Rabitsch W et al (2010) Socioeconomic legacy yields an invasion debt. Proc Natl Acad Sci 108:203–207. https://doi.org/10.1073/pnas.1011728108
Fahey RT, Bowles ML, McBride JL (2012) Origins of the Chicago urban forest: composition and structure in relation to presettlement vegetation and modern land use. Arboricult Urban For 38:181–193
Fahey RT, Casali M (2017) Distribution of forest ecosystems over two centuries in a highly urbanized landscape. Landsc Urban Plan 164:13–24. https://doi.org/10.1016/j.landurbplan.2017.03.008
Farmer JR, Knapp D, Meretsky VJ et al (2011) Motivations influencing the adoption of conservation easements. Conserv Biol 25:827–834. https://doi.org/10.1111/j.1523-1739.2011.01686.x
Finney C (2014) Black Faces, White Spaces: Reimagining the Relationship of African Americans to the Great Outdoors. UNC Press Books
Fisher DR, Svendsen ES, Connolly J et al (2015) Urban environmental stewardship and civic engagement: how planting trees strengthens the roots of democracy. Routledge
Folke C, Carpenter S, Walker B et al (2010) Resilience thinking: integrating resilience, adaptability and transformability. Ecol Soc 15:20
Forman RTT (1995) Some general principles of landscape and regional ecology. Landsc Ecol 10:133–142. https://doi.org/10.1007/BF00133027
Forman RTT, Godron M (1981) Patches and structural components for a landscape ecology. BioScience 31:733–740. https://doi.org/10.2307/1308780
Frank S, Waters G, Beer R, May P (2006) An analysis of the street tree population of greater Melbourne at the beginning of the 21st century Arboric. Urban For 32:155–163
Godefroid S, Koedam N (2003a) Distribution pattern of the flora in a peri-urban forest: an effect of the city–forest ecotone. Landsc Urban Plan 65:169–185. https://doi.org/10.1016/S0169-2046(03)00013-6
Godefroid S, Koedam N (2003b) How important are large vs. small forest remnants for the conservation of the woodland flora in an urban context? Glob Ecol Biogeogr 12:287–298. https://doi.org/10.1046/j.1466-822X.2003.00035.x
Gong C, Yu S, Joesting H, Chen J (2013) Determining socioeconomic drivers of urban forest fragmentation with historical remote sensing images. Landsc Urban Plan 117:57–65. https://doi.org/10.1016/j.landurbplan.2013.04.009
Gunnarsson B, Knez I, Hedblom M, Sang ÅO (2017) Effects of biodiversity and environment-related attitude on perception of urban green space. Urban Ecosyst 20:37–49. https://doi.org/10.1007/s11252-016-0581-x
Halpenny EA (2010) Pro-environmental behaviours and park visitors: the effect of place attachment. J Environ Psychol 30:409–421. https://doi.org/10.1016/j.jenvp.2010.04.006
Hamberg L, Lehvävirta S, Kotze DJ (2009) Forest edge structure as a shaping factor of understorey vegetation in urban forests in Finland. For Ecol Manag 257:712–722. https://doi.org/10.1016/j.foreco.2008.10.003
Hamberg L, Malmivaara-Lämsä M, Lehvävirta S et al (2010) Quantifying the effects of trampling and habitat edges on forest understory vegetation – a field experiment. J Environ Manag 91:1811–1820. https://doi.org/10.1016/j.jenvman.2010.04.003
Handley K, Hough-Goldstein J, Hanks LM et al (2015) Species richness and phenology of Cerambycid beetles in Urban Forest fragments of northern Delaware. esaa 108:251–262. https://doi.org/10.1093/aesa/sav005
Hauru K, Lehvävirta S, Korpela K, Kotze DJ (2012) Closure of view to the urban matrix has positive effects on perceived restorativeness in urban forests in Helsinki, Finland. Landsc Urban Plan 107:361–369. https://doi.org/10.1016/j.landurbplan.2012.07.002
Heynen N, Kaika M, Swyngedouw E (2006) In the nature of cities: urban political ecology and the politics of urban metabolism. Routledge, London
Hopfensperger KN, Leighton GM, Fahey TJ (2011) Influence of invasive earthworms on above and belowground vegetation in a northern hardwood Forest. amid 166:53–62. https://doi.org/10.1674/0003-0031-166.1.53
Ignatieva M, Stewart GH, Meurk C (2011) Planning and design of ecological networks in urban areas. Landscape Ecol Eng 7:17–25. https://doi.org/10.1007/s11355-010-0143-y
Imhoff ML, Bounoua L, DeFries R et al (2004) The consequences of urban land transformation on net primary productivity in the United States. Remote Sens Environ 89:434–443. https://doi.org/10.1016/j.rse.2003.10.015
Irwin EG, Geoghegan J (2001) Theory, data, methods: developing spatially explicit economic models of land use change. Agric Ecosyst Environ 85:7–24. https://doi.org/10.1016/S0167-8809(01)00200-6
Jackson KT (1987) Crabgrass Frontier: The Suburbanization of the United States. Oxford University Press
Jansson M, Fors H, Lindgren T, Wiström B (2013) Perceived personal safety in relation to urban woodland vegetation – A review. https://doi.org/10.1016/j.ufug.2013.01.005. Accessed 1 Aug 2019
Johnson LR, Handel SN (2016) Restoration treatments in urban park forests drive long-term changes in vegetation trajectories. Ecol Appl 26:940–956. https://doi.org/10.1890/14-2063
Johnson LR, Handel SN (2019) Management intensity steers the long-term fate of ecological restoration in urban woodlands. Urban For Urban Green. https://doi.org/10.1016/j.ufug.2019.02.008
Johnson ML, Auyeung DSN, Sonti NF et al (2018) Social-ecological research in urban natural areas: an emergent process for integration. Urban Ecosyst 36:495. https://doi.org/10.1007/s11252-018-0763-9
Johnson MTJ, Munshi-South J (2017) Evolution of life in urban environments. Science 358:eaam8327. https://doi.org/10.1126/science.aam8327
Jorgensen A, Hitchmough J, Calvert T (2002) Woodland spaces and edges: their impact on perception of safety and preference. Landsc Urban Plan 60:135–150. https://doi.org/10.1016/S0169-2046(02)00052-X

Kang W, Minor ES, Park C-R, Lee D (2015) Effects of habitat structure, human disturbance, and habitat connectivity on urban forest bird communities. Urban Ecosyst 18:857–870. https://doi.org/10.1007/s11252-014-0433-5

Kantsa A, Tscheulin T, Junker RR et al (2013) Urban biodiversity hotspots wait to get discovered: the example of the city of Ioannina, NW Greece. Landsc Urban Plan 120:129–137. https://doi.org/10.1016/j.landurbplan.2013.08.013

Kapoutsis I, Papalexandris A, Treadway DC, Bentley J (2017) Measuring political will in organizations: theoretical construct development and empirical validation. J Manag 43:2252–2280. https://doi.org/10.1177/0149206314566460

Konijnendijk CC (2003) A decade of urban forestry in Europe. Forest Policy Econ 5:173–186. https://doi.org/10.1016/S1389-9341(03)00023-6

Konijnendijk CC (2005) New perspectives for Urban forests: introducing wild woodlands. In: Kowarik I, Körner S (eds) Wild Urban woodlands: new perspectives for Urban forestry. Springer, Berlin, pp 33–45

Konijnendijk CC, Ricard RM, Kenney A, Randrup TB (2006) Defining urban forestry – a comparative perspective of North America and Europe. Urban For Urban Green 4:93–103. https://doi.org/10.1016/j.ufug.2005.11.003

Korpela KM, Ylén M, Tyrväinen L, Silvennoinen H (2010) Favorite green, waterside and urban environments, restorative experiences and perceived health in Finland. Health Promot Int 25:200–209. https://doi.org/10.1093/heapro/daq007

Kostel-Hughes F, Young TP, Carreiro MM (1998) Forest leaf litter quantity and seedling occurrence along an urban-rural gradient. Urban Ecosyst 2:263–278. https://doi.org/10.1023/A:1009536706827

Kowarik I (2011) Novel urban ecosystems, biodiversity, and conservation. Selected papers from the conference Urban Environmental Pollution: Overcoming Obstacles to Sustainability and Quality of Life (UEP2010), 20–23 June 2010, Boston, USA 159:1974–1983. https://doi.org/10.1016/j.envpol.2011.02.022

Kowarik I, Körner S (eds) (2005) Wild Urban woodlands: new perspectives for Urban forestry. Springer, Berlin

La Sorte FA, Aronson MFJ, Williams NSG et al (2014) Beta diversity of urban floras among European and non-European cities. Glob Ecol Biogeogr 23:769–779. https://doi.org/10.1111/geb.12159

Labatore AC, Spiering DJ, Potts DL, Warren RJ (2017) Canopy trees in an urban landscape – viable forests or long-lived gardens? Urban Ecosyst 20:393–401. https://doi.org/10.1007/s11252-016-0601-x

Ladin ZS, D'Amico V, Baetens JM et al (2016) Predicting metapopulation responses to conservation in human-dominated landscapes. Front Ecol Evol 4. https://doi.org/10.3389/fevo.2016.00122

Latour B (2005) Reassembling the social: an introduction to actor-network-theory. Oxford University Press, Oxford

Lawrence A, De Vreese R, Johnston M et al (2013) Urban forest governance: towards a framework for comparing approaches. Urban For Urban Green 12:464–473. https://doi.org/10.1016/j.ufug.2013.05.002

Lawrence HW (1993) The neoclassical origins of modern Urban forests. Forest Conserv Hist 37:26–36. https://doi.org/10.2307/3983816

Lawrence W (1997) From private Allee to public shade tree: historic roots of the Urban Forest. Arnoldia 57:8

Lehvävirta S, Kotze DJ, Niemelä J et al (2006) Effects of fragmentation and trampling on carabid beetle assemblages in urban woodlands in Helsinki, Finland. Urban Ecosyst 9:13–26. https://doi.org/10.1007/s11252-006-5526-3

Lemos MC, Agrawal A (2006) Environmental governance. Annu Rev Environ Resour 31:297–325. https://doi.org/10.1146/annurev.energy.31.042605.135621

Lepczyk CA, Aronson MFJ, Evans KL et al (2017a) Biodiversity in the City: fundamental questions for understanding the ecology of Urban green spaces for biodiversity conservation. BioScience 67:799–807. https://doi.org/10.1093/biosci/bix079

Lepczyk CA, La Sorte FA, Aronson MFJ et al (2017b) Global patterns and drivers of Urban bird diversity. In: Murgui E, Hedblom M (eds) Ecology and conservation of birds in Urban environments. Springer International Publishing, Cham, pp 13–33

Lerman SB, Turner VK, Bang C (2012) Homeowner associations as a vehicle for promoting native urban biodiversity. Ecol Soc 17. https://doi.org/10.5751/ES-05175-170445

Li W, Saphores J-D (2012) A spatial hedonic analysis of the value of Urban land cover in the multifamily housing market in Los Angeles, CA. Urban Stud 49:2597–2615. https://doi.org/10.1177/0042098011429486

Loeb RE (1989) The ecological history of an urban park. J For Hist 33:134–143

Loeb RE (1992) Long-term human disturbance of an urban park forest, new York City. For Ecol Manag 49:293–309. https://doi.org/10.1016/0378-1127(92)90142-V

Löfvenhaft K, Björn C, Ihse M (2002) Biotope patterns in urban areas: a conceptual model integrating biodiversity issues in spatial planning. Landsc Urban Plan 58:223–240. https://doi.org/10.1016/S0169-2046(01)00223-7

Londré RA, Schnitzer SA (2006) The distribution of lianas and their change in abundance in temperate forests over the past 45 years. Ecology 87:2973–2978. https://doi.org/10.1890/0012-9658(2006)87[2973:TDOLAT]2.0.CO;2

Lopez BE, Urban D, White PS (2018) Nativity and seed dispersal mode influence species' responses to habitat connectivity and urban environments. Glob Ecol Biogeogr 27:1017–1030. https://doi.org/10.1111/geb.12760

Lovell ST, Taylor JR (2013) Supplying urban ecosystem services through multifunctional green infrastructure in the United States. Landsc Ecol 28:1447–1463. https://doi.org/10.1007/s10980-013-9912-y

Malmivaara-Lämsä M, Hamberg L, Haapamaki E et al (2008) Edge effects and trampling in boreal urban forest fragments – impacts on the soil microbial community. Soil Biol Biochem 40:1612–1621. https://doi.org/10.1016/j.soilbio.2008.01.013

Maruthaveeran S, Konijnendijk van den Bosch CC (2014) A socio-ecological exploration of fear of crime in urban green spaces – a systematic review. Urban For Urban Green 13:1–18

Matlack GR (1993) Sociological edge effects: spatial distribution of human impact in suburban forest fragments. Environ Manag 17:829–835. https://doi.org/10.1007/BF02393903

McBride JR, Jacobs DF (1986) Presettlement forest structure as a factor in urban forest development. Urban Ecol 9:245–266. https://doi.org/10.1016/0304-4009(86)90003-3

McCary MA, Minor E, Wise DH (2018) Covariation between local and landscape factors influences the structure of ground-active arthropod communities in fragmented metropolitan woodlands. Landsc Ecol 33:225–239. https://doi.org/10.1007/s10980-017-0593-9

McDonnell MJ, Hahs AK (2008) The use of gradient analysis studies in advancing our understanding of the ecology of urbanizing landscapes: current status and future directions. Landsc Ecol 23:1143–1155. https://doi.org/10.1007/s10980-008-9253-4

McDonnell MJ, Pickett STA (1990) Ecosystem structure and function along Urban-rural gradients: an unexploited opportunity for ecology. Ecology 71:1232–1237. https://doi.org/10.2307/1938259

McDonnell MJ, Pickett STA, Groffman P et al (1997) Ecosystem processes along an urban-to-rural gradient. Urban Ecosyst 1:21–36. https://doi.org/10.1023/A:1014359024275

McGarigal K, Marks BJ (1995) Fragstats: spatial pattern analysis program for quantifying landscape structure. Pacific Northwest Research Station, USDA Forest Service, Portland

McLain RJ, Hurley PT, Emery MR, Poe MR (2014) Gathering "wild" food in the city: rethinking the role of foraging in urban ecosystem planning and management. Local Environ 19:220–240. https://doi.org/10.1080/13549839.2013.841659

MEA (2005) Millennium Ecosystem Assessment: Ecosystems and human well-being biodiversity synthesis. United Nations Environment Programme, World Resources Institute, Washington, DC

Miller J (2005) Biodiversity conservation and the extinction of experience. Trends Ecol Evol 20:430–434. https://doi.org/10.1016/j.tree.2005.05.013

Moons P, Budts W, De Geest S (2006) Critique on the conceptualisation of quality of life: a review and evaluation of different conceptual approaches. Int J Nurs Stud 43:891–901. https://doi.org/10.1016/j.ijnurstu.2006.03.015

Morzillo AT, Kreakie BJ, Netusil NR, et al (2016) Resident perceptions of natural resources between cities and across scales in the Pacific Northwest. https://doi.org/10.5751/ES-08478-210314

Müller A, Bøcher PK, Fischer C, Svenning J-C (2018) 'Wild' in the city context: do relative wild areas offer opportunities for urban biodiversity? Landsc Urban Plan 170:256–265. https://doi.org/10.1016/j.landurbplan.2017.09.027

Nagy RC, Lockaby BG, Zipperer WC, Marzen LJ (2014) A comparison of carbon and nitrogen stocks among land uses/covers in coastal Florida. Urban Ecosyst 17:255–276. https://doi.org/10.1007/s11252-013-0312-5

Nowak DJ, Noble MH, Sisinni SM, Dwyer JF (2001) People and trees: assessing the US urban forest resource. J 99:37–42. https://doi.org/10.1093/jof/99.3.37

Ode Sang Å, Knez I, Gunnarsson B, Hedblom M (2016) The effects of naturalness, gender, and age on how urban green space is perceived and used. Urban For Urban Green 18:268–276. https://doi.org/10.1016/j.ufug.2016.06.008

Ogden LA, Aoki C, Grove JM et al (2019) Forest ethnography: an approach to study the environmental history and political ecology of urban forests. Urban Ecosyst 22:49–63. https://doi.org/10.1007/s11252-018-0744-z

Oldfield EE, Warren RJ, Felson AJ, Bradford MA (2013) Challenges and future directions in urban afforestation. J Appl Ecol n/a-n/a. https://doi.org/10.1111/1365-2664.12124

Ordóñez C, Duinker PN (2013) An analysis of urban forest management plans in Canada: implications for urban forest management. Landsc Urban Plan 116:36–47. https://doi.org/10.1016/j.landurbplan.2013.04.007

Ostoić SK, Konijnendijk van den Bosch CC, Vuletić D et al (2017) Citizens' perception of and satisfaction with urban forests and green space: results from selected southeast European cities. Urban For Urban Green 23:93–103. https://doi.org/10.1016/j.ufug.2017.02.005

Palmer MA, Kramer JG, Boyd J, Hawthorne D (2016) Practices for facilitating interdisciplinary synthetic research: the National Socio-Environmental Synthesis Center (SESYNC). Curr Opin Environ Sustain 19:111–122. https://doi.org/10.1016/j.cosust.2016.01.002

Perkins HA (2007) Ecologies of actor-networks and (non)social labor within the urban political economies of nature. Geoforum 6:1152–1162. https://doi.org/10.1016/j.geoforum.2007.01.007

Piana MR, Aronson MF, Pickett ST, Handel SN (2019) Plants in the city: understanding recruitment dynamics in urban landscapes. Front Ecol Environ 17:455–463. https://doi.org/10.1002/fee.2098

Pickett ST, Cadenasso ML, Grove JM et al (2008) Urban ecological systems: linking terrestrial ecological, physical, and socioeconomic components of metropolitan areas. In: Urban Ecology. Springer, pp 99–122

Pickett STA, Cadenasso ML (2009) Altered resources, disturbance, and heterogeneity: a framework for comparing urban and non-urban soils. Urban Ecosyst 12:23–67

Pickett STA, Cadenasso ML, Rosi-Marshall EJ et al (2017) Dynamic heterogeneity: a framework to promote ecological integration and hypothesis generation in urban systems. Urban Ecosyst 20:1–14. https://doi.org/10.1007/s11252-016-0574-9

Pickett STA, Collins SL, Armesto JJ (1987) Models, mechanisms and pathways of succession. Bot Rev 53:335–371

Pickett STA, Meiners SJ, Cadenasso ML (2011) Domain and propositions of succession theory. In: Scheiner S, Willig M (eds) The theory of ecology. University of Chicago Press, Chicago, pp 185–216

Pouyat R, Yesilonis I, Russell-Anelli J, Neerchal N (2007) Soil chemical and physical properties that differentiate urban land-use and cover types. Soil Sci Soc Am J 71:1010–1019

Pouyat RV, Carreiro MM, Groffman PM, Pavao-Zuckerman MA (2009) Investigative approaches to urban biogeochemical cycles: New York metropolitan area and Baltimore as case studies. Ecol Cities Towns A Comp Approach. https://doi.org/10.1017/CBO9780511609763.021

Power ER (2005) Human–nature relations in suburban gardens. Aust Geogr 36:39–53. https://doi.org/10.1080/00049180500050847

Pregitzer CC, Ashton MS, Charlop-Powers S et al (2019) Defining and assessing urban forests to inform management and policy. Environ Res Lett 14:085002. https://doi.org/10.1088/1748-9326/ab2552

Pregitzer CC, Charlop-Powers S, Bibbo S, et al (2018) A city-scale assessment reveals that native forest types and overstory species dominate New York City forests. Ecol Appl 0. https://doi.org/10.1002/eap.1819

Pregitzer CC, Sonti NF, Hallett RA (2016) Variability in Urban soils influences the health and growth of native tree seedlings. Ecol Res 34:106–116. https://doi.org/10.3368/er.34.2.106

Quartuch MR, Beckley TM (2014) Carrots and sticks: New Brunswick and Maine Forest landowner perceptions toward incentives and regulations. Environ Manag 53:202–218. https://doi.org/10.1007/s00267-013-0200-z

Rebelo AG, Holmes PM, Dorse C, Wood J (2011) Impacts of urbanization in a biodiversity hotspot: conservation challenges in metropolitan Cape Town. S Afr J Bot 77:20–35. https://doi.org/10.1016/j.sajb.2010.04.006

Rink D, Arndt T (2016) Investigating perception of green structure configuration for afforestation in urban brownfield development by visual methods—a case study in Leipzig, Germany. Urban For Urban Green 15:65–74. https://doi.org/10.1016/j.ufug.2015.11.010

Ripplinger J, Collins SL, York AM, Franklin J (2017) Boom–bust economics and vegetation dynamics in a desert city: how strong is the link? Ecosphere 8:e01826. https://doi.org/10.1002/ecs2.1826

Robbins P (2012) Lawn people: how grasses, weeds, and chemicals make us who we are. Temple University Press

Robinson GR, Handel SN (2000) Directing spatial patterns of recruitment during an experimental urban woodland reclamation. Ecol Appl 10:174–188. https://doi.org/10.2307/2640994

Rogers GF, Rowntree RA (1988) Intensive surveys of structure and change in urban natural areas. Landsc Urban Plan 15:59–78. https://doi.org/10.1016/0169-2046(88)90016-3

Roman LA, Pearsall H, Eisenman TS et al (2018) Human and biophysical legacies shape contemporary urban forests: a literature synthesis. Urban For Urban Green 31:157–168. https://doi.org/10.1016/j.ufug.2018.03.004

Roovers P, Hermy M, Gulinck H (2002) Visitor profile, perceptions and expectations in forests from a gradient of increasing urbanisation in Central Belgium. Landsc Urban Plan 59:129–145. https://doi.org/10.1016/S0169-2046(02)00011-7

Rupprecht CDD, Byrne JA (2014) Informal urban greenspace: a typology and trilingual systematic review of its role for urban residents and trends in the literature. Urban For Urban Green 13:597–611. https://doi.org/10.1016/j.ufug.2014.09.002

Ryan RL (2005) Exploring the effects of environmental experience on attachment to Urban natural areas. Environ Behav 37:3–42. https://doi.org/10.1177/0013916504264147

Sanesi G, Colangelo G, Lafortezza R et al (2017) Urban green infrastructure and urban forests: a case study of the metropolitan area of Milan. Landsc Res 42:164–175. https://doi.org/10.1080/01426397.2016.1173658

Saphores J-D, Li W (2012) Estimating the value of urban green areas: a hedonic pricing analysis of the single family housing market in Los Angeles, CA. Landsc Urban Plan 104:373–387. https://doi.org/10.1016/j.landurbplan.2011.11.012

Schmidt S, Paulsen K (2009) Is open-space preservation a form of exclusionary zoning?: the evolution of municipal open-space policies in

New Jersey. Urban Aff Rev 45:92–118. https://doi.org/10.1177/1078087408331122

Schwartz MW, Jurjavcic NL, O'Brien JM (2002) Conservation's disenfranchised Urban poor. BioScience 52:601–606. https://doi.org/10.1641/0006-3568(2002)052[0601:CSDUP]2.0.CO;2

Shackleton CM, Hurley PT, Dahlberg AC et al (2017) Urban foraging: a ubiquitous human practice overlooked by Urban planners, policy, and research. Sustainability 9:1884. https://doi.org/10.3390/su9101884

Shanahan DF, Lin BB, Gaston KJ et al (2015) What is the role of trees and remnant vegetation in attracting people to urban parks? Landsc Ecol 30:153–165. https://doi.org/10.1007/s10980-014-0113-0

Sharpe DM, Stearns F, Leitner LA, Dorney JR (1986) Fate of natural vegetation during urban development of rural landscapes in southeastern Wisconsin. Urban Ecol 9:267–287. https://doi.org/10.1016/0304-4009(86)90004-5

Simmons BL, Hallett RA, Sonti NF et al (2016) Long-term outcomes of forest restoration in an urban park. Restor Ecol 24:109–118. https://doi.org/10.1111/rec.12281

Soanes K, Sievers M, Chee YE et al (2019) Correcting common misconceptions to inspire conservation action in urban environments. Conserv Biol 33:300–306. https://doi.org/10.1111/cobi.13193

Soga M, Gaston KJ (2016) Extinction of experience: the loss of human–nature interactions. Front Ecol Environ 14:94–101. https://doi.org/10.1002/fee.1225

Song C, Ikei H, Miyazaki Y (2016) Physiological effects of nature therapy: a review of the research in Japan. Int J Environ Res Public Health 13. https://doi.org/10.3390/ijerph13080781

Sonti NF (2019) Ambivalence in the woods: Baltimore resident perceptions of local Forest patches. Soc Nat Resour 0:1–19. https://doi.org/10.1080/08941920.2019.1701162

Sonti NF, Campbell LK, Svendsen ES et al (2020) Fear and fascination: use and perceptions of New York City's forests, wetlands, and landscaped park areas. Urban Forestry & Urban Greening

Sukopp H (2008a) The city as a subject for ecological research. Urban Ecology

Sukopp H (2008b) On the early history of urban ecology in Europe. In: Shulenberger E, Endlicher W, Alberti Marina et al. (eds) Urban ecology: an international perspective on the interaction between humans and nature, 2008th edn. Springer

Sukopp H, Weiler S (1988) Biotope mapping and nature conservation strategies in urban areas of the Federal Republic of Germany. Landsc Urban Plan 15:39–58. https://doi.org/10.1016/0169-2046(88)90015-1

Svendsen E, Campbell L (2008) Urban ecological stewardship: understanding the structure, function and network of community-based urban land management. Cities and the Environment (CATE) 1

Talen E (2012) City rules: how regulations affect urban form. Island Press

Taylor D (1993) Urban park use: race, ancestry, and gender managing urban and high-use recreational settings. North Central Forest Experiment Station, USDA Forest Service

Thompson CW, Aspinall P, Montarzino A (2007) The childhood factor: adult visits to green places and the significance of childhood experience. Environ Behav. https://doi.org/10.1177/0013916507300119

Toni SA, Duinker PN (2015) A framework for urban–woodland naturalization in Canada. Environ Rev 23:321–336. https://doi.org/10.1139/er-2015-0003

Turner GD, Van Meter RJ, Hertel GD (2007) Changes in forest understory composition from 1970 to 2003 at the Gordon natural area, an urban preserve in Chester County, Pennsylvania. J Pennsylvania Acad Sci 81:8–13

Tyrväinen L, Pauleit S, Seeland K, de Vries S (2005) Benefits and uses of Urban forests and trees. In: Konijnendijk C, Nilsson K, Randrup T, Schipperijn J (eds) Urban forests and trees: a reference book. Springer, Berlin, pp 81–114

Urban Wood Network (2017) Urban Wood Network. In: Urban Wood Network. http://urbanwoodnetwork.org/about. Accessed 25 Jul 2019

Virden RJ, Walker GJ (1999) Ethnic/racial and gender variations among meanings given to, and preferences for, the natural environment. Leis Sci 21:219–239. https://doi.org/10.1080/014904099273110

Vogt J, Epstein G, Mincey S, et al (2015) Putting the "E" in SES: unpacking the ecology in the Ostrom social-ecological system framework. Ecol Soc 20. https://doi.org/10.5751/ES-07239-200155

von der Lippe M, Kowarik I (2008) Do cities export biodiversity? Traffic as dispersal vector across urban–rural gradients. Divers Distrib 14:18–25. https://doi.org/10.1111/j.1472-4642.2007.00401.x

White PS, Pickett STA (1985) Natural disturbance and patch dynamics: an introduction. In: The ecology of natural disturbance and patch dynamics. Academic Press, San Diego, pp 3–13

Wu J (2014) Urban ecology and sustainability: the state-of-the-science and future directions. Landsc Urban Plan 125:209–221. https://doi.org/10.1016/j.landurbplan.2014.01.018

Zhu W, Carreiro MM (2004) Temporal and spatial variations in nitrogen transformations in deciduous forest ecosystems along an urban–rural gradient. Soil Biol Biochem 36. https://doi.org/10.1016/j.soilbio.2003.09.013

Zipperer WC, Foresman TW, Walker SP, Daniel CT (2012) Ecological consequences of fragmentation and deforestation in an urban landscape: a case study. Urban Ecosyst 15:533–544. https://doi.org/10.1007/s11252-012-0238-3

Ziska LH, Bunce JA, Goins EW (2004) Characterization of an urban-rural CO_2/temperature gradient and associated changes in initial plant productivity during secondary succession. Oecologia 139:454–458. https://doi.org/10.1007/s00442-004-1526-2