

# Growing Canopy on a College Campus: Understanding Urban Forest Change through Archival Records and Aerial Photography

Lara A. Roman<sup>1</sup> · Jason P. Fristensky<sup>1,2</sup> · Theodore S. Eisenman<sup>3</sup> ·  
Eric J. Greenfield<sup>4</sup> · Robert E. Lundgren<sup>5</sup> · Chloe E. Cerwinka<sup>5</sup> · David A. Hewitt<sup>6</sup> ·  
Caitlin C. Welsh<sup>5</sup>

Received: 17 February 2017 / Accepted: 22 August 2017 / Published online: 13 September 2017  
© Springer Science+Business Media, LLC (outside the USA) 2017

**Abstract** Many municipalities are setting ambitious tree canopy cover goals to increase the extent of their urban forests. A historical perspective on urban forest development can help cities strategize how to establish and achieve appropriate tree cover targets. To understand how long-term urban forest change occurs, we examined the history of trees on an urban college campus: the University of Pennsylvania in Philadelphia, PA. Using a mixed methods approach, including qualitative assessments of archival records (1870–2017), complemented by quantitative analysis of tree cover from aerial imagery (1970–2012), our analysis revealed drastic canopy cover increase in the late 20th and early 21st centuries along with the principle mechanisms of that change. We organized the historical narrative into periods reflecting campus planting actions and management approaches; these periods are also connected to broader urban greening and city planning movements, such as City Beautiful and urban sustainability. University

faculty in botany, landscape architecture, and urban design contributed to the design of campus green spaces, developed comprehensive landscape plans, and advocated for campus trees. A 1977 Landscape Development Plan was particularly influential, setting forth design principles and planting recommendations that enabled the dramatic canopy cover gains we observed, and continue to guide landscape management today. Our results indicate that increasing urban tree cover requires generational time scales and systematic management coupled with a clear urban design vision and long-term commitments. With the campus as a microcosm of broader trends in urban forest development, we conclude with a discussion of implications for municipal tree cover planning.

**Keywords** City planning history · Landscape design · Sustainable campus · Urban ecology · Urban environmental history · Urban tree canopy

---

✉ Lara A. Roman  
lroman@fs.fed.us

<sup>1</sup> USDA Forest Service, Northern Research Station, Philadelphia Research Station, 100 N. 20th Street, Suite 205, Philadelphia, PA 19103, USA

<sup>2</sup> Berger Partnership, 1721 8th Ave North, Seattle, WA 98109, USA

<sup>3</sup> Dept. of Landscape Architecture and Regional Planning, University of Massachusetts, Amherst, 402 Hills North, 111 Thatcher Road, Amherst, MA 01003, USA

<sup>4</sup> USDA Forest Service, Northern Research Station, 5 Moon Library, SUNY-ESF, 1 Forestry Drive, Syracuse, NY 13210, USA

<sup>5</sup> Facilities & Real Estate Services, University of Pennsylvania, 3101 Walnut St., Philadelphia, PA 19104, USA

<sup>6</sup> Wagner Free Institute of Science, 1700 West Montgomery Avenue, Philadelphia, PA 19121, USA

## Introduction

Many municipalities are pursuing massive tree planting initiatives and setting ambitious canopy cover goals to address urban sustainability (Young and McPherson 2013; Locke et al. 2013). Tree canopy in the early 2000s has, however, declined in many US cities, indicating that tree losses may outweigh planting efforts (Nowak and Greenfield 2012). A historical perspective on the rates of canopy cover change and management actions related to such changes can help cities establish and achieve canopy cover targets going forward. Furthermore, there is a temporal lag between tree planting and the realization of substantial

canopy gains, as trees do not mature instantaneously (Grove et al. 2014). Studies with a long-term horizon are therefore essential to uncover the impacts of past events on contemporary canopy. Indeed, in explaining contemporary tree cover patterns, historical socioeconomic variables can be effective predictors (Boone et al. 2010).

Studies of urban forest development have identified important factors impacting urban forests over decades to centuries: remnants of pre-urbanization vegetation, pest and fire disturbance, and land use decisions by homeowners, community organizations, and public agencies (McBride and Jacobs 1986; McPherson and Luttinger 1998). For example, Sacramento, California transitioned from City of the Plains to City of Trees through a series of cultural and ecological forces, including early tree planting rooted in concerns for human health and a desire for horticultural displays, engagement by civic actors, and management responses to storms and pests (McPherson and Luttinger 1998). Legacies of such historic factors shape today's urban forest.

Another group of studies has documented changes in the geographic extent of urban forests over the time frame necessary for trees to grow. Zipperer and colleagues' (1997) model of urban tree cover change posits that tree cover generally increases after the establishment of human settlements in desert and grassland systems, but declines post-settlement in forested ecoregions. Consistent with that model, in the Mediterranean climate of the western United States (US), there has been a substantial increase in the extent of the urban forest of Los Angeles, California: mean tree density increased from 40 trees/ha in the 1920s to over 100 trees/ha in 2006 (Gillespie et al. 2012). In the mid-western US prairies and farmlands, canopy cover in the Twin Cities, Minnesota doubled from 17 to 33% from 1937 to 2009 during urbanization (Berland 2012). On the other hand, assessments of 20th century canopy cover in cities within forested ecoregions have found relatively stable tree cover during conversion from agriculture to urbanized land use. For example, total forest area had only a slight change, from 18 to 21%, between 1914 and 2004 in Baltimore, Maryland (Zhou et al. 2011). Notably, tree cover trajectories can vary across neighborhoods (Zhou et al. 2011; Gillespie et al. 2012). Zooming into changes at local spatial scales can illuminate the influence of particular actors and events (Locke et al. 2014).

To unpack long-term urban forest development at a fine geographic resolution, we examined the history of trees on an urban college campus: the University of Pennsylvania (Penn) in Philadelphia. Our goal was to understand how urban forest change occurred in this landscape over nearly 150 years, necessitating qualitative and quantitative approaches. We drew upon historical investigation of archival records, as well as analysis of tree cover change

using aerial imagery. Our findings are structured as a historical chronology, focusing on key events and actors that shaped the campus canopy. We then connect this narrative to larger movements in city planning history, and contextualize the implications of this research for cities pursuing canopy cover goals.

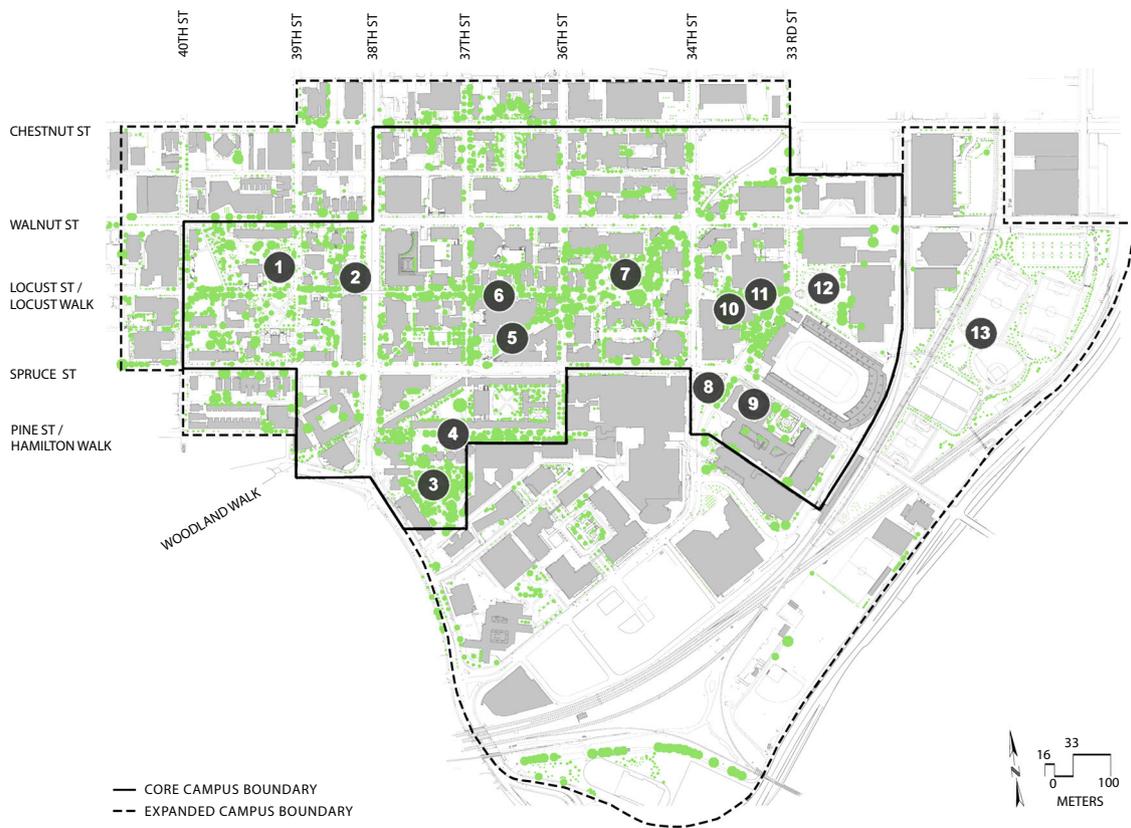
### The College Campus as a Sylvan Landscape

To connect our campus study to the broader urban forestry discourse, we briefly review literature concerning college campuses as sylvan landscapes. Turner (1984) argues that the college campus is a uniquely American type of landscape. Whereas European universities are often located in cities, many US college campuses are located in more rural settings. While this may be partially due to land availability, it also reflects romantic, transcendental notions of pastoral nature as inherently more beautiful and uplifting than cities. Trees figure prominently in creating this naturalistic aesthetic, an ideal so strong that even schools located in cities have often gone to considerable lengths to simulate a rural character. In the 1840s, Charles Dickens remarked that the landscape of trees and buildings at Yale University in New Haven, Connecticut created an effect that “bring[s] about a kind of compromise between town and country” (Dickens 1842, 1:183).

Many American college campuses are designed as open, extroverted spaces that serve not only students and staff, but also the surrounding population. As such, the landscape is both an environment for learning and a public space. The College of Charleston, South Carolina is characterized as “an academical park in the center of town” (Russell 2006, 146). The University of California, Berkeley campus has been described as one of the most precious public parks in an increasingly built-up area, while a Newark, Delaware resident commented that without the University of Delaware campus, “there would be no park” in the city (Gumprecht 2007, 86).

In recent years, sustainability has become an important principle for college campuses and tree planting initiatives are part of this trend (Koester et al. 2006). The Arbor Day Foundation has made environmental stewardship and climate change mitigation central to its Tree Campus USA program (Arbor Day Foundation 2013). Universities are also setting targets for tree cover (University of Michigan 2011; Georgia Institute of Technology 2014) and have estimated the ecosystem services of campus trees (Bassett 2015). College campuses are thus embedded within the larger urban forestry discourse, using ecosystem services and canopy cover goals for management and policy in ways similar to municipalities.

Campus trees have likewise been used for urban forest research, including studies about dendrochronology



**Fig. 1** Map of Penn's campus showing boundaries and places described in the manuscript: (1) Superblock, (2) Class of 1942 Garden at Kelly Writers House, (3) James G. Kaskey Memorial Park (also known as the Botanic Garden), (4) Hamilton Walk, (5) McHarg Gardens along Woodland Walk, (6) Locust Walk, (7) Blanche Levy Park (also known as College Green), (8) Edward G. Kane Park, (9)

Penn Museum of Archaeology and Anthropology, (10) Class of 1957 Geology Garden, (11) Smith Walk, (12) Shoemaker Green, (13) Penn Park. Solid gray represents buildings. Green represents tree canopy cover, as measured on the field in 2014 (tree canopy data is partially complete for the expanded campus)

(Copenheaver et al. 2014) and inventory design (Martin et al. 2013). Such studies have contributed to arboricultural science by treating university grounds as an experimental landscape. Our study follows in this tradition, using historical investigation of trees in a highly urbanized campus to investigate broader themes of urban forest change.

## Methods

We employed a case study approach. Case studies investigate phenomena in-depth and within a real-world context (Yin 2009). Such detailed and holistic analyses are appropriate to study how phenomena actually occur in a situated context (Creswell 2013). The co-authors are mostly current or former staff or students at Penn, including the University Landscape Architect, who has managed campus vegetation since 1994. We are therefore embedded within the University and have situated experiences that shaped the framing of our findings (Mansvelt and Berg 2005). Our study employed mixed methods, integrating historical

narrative of urban forest development with quantitative analysis of tree cover change.

## Study Area

Penn is a private university and one of the oldest institutions of higher learning in the US. The University was founded in 1740 and acquired the West Philadelphia campus, just west of the Schuylkill River, in 1870, occupying the space in 1872. Within the current campus, we used two different boundaries for our analysis (Fig. 1): the core campus (65.1 ha) and the expanded campus (149.9 ha). Vegetation management on the core campus is overseen by the University Landscape Architect. The expanded campus includes areas with vegetation managed by different parties.

Penn's campus is located across the Atlantic Coastal Plain and the Piedmont (Paulachok 1991); therefore, prior to European colonization it would have been closed canopy forest with swamps and marshes in lowland areas along the river. Like the rest of the northeastern US, this area was deforested during colonization, and by the end of the 19th

century, “[in] a state that had been named for forests and had once been virtually blanketed with trees, Penn’s woods had almost vanished” (Stroud 2015, 20). The state and the city then gained back canopy through conservation and afforestation (Armstrong 2012; Stroud 2015).

### Archival Records: 1870–2017

To investigate Penn’s urban forest history, we searched archival records for documents related to trees. Campus plans from the Penn archives were identified by the University Landscape Architect and University Archivist. In digital records from the archives and University newspapers, we searched for the following terms: campus tree, tree planting, urban forest, campus landscape, landscape plan, campus master plan, green campus, as well as place names in Fig. 1. Newspapers searched were *The Pennsylvania Gazette* (alumni magazine), *The Daily Pennsylvanian* (student newspaper), and *Almanac* (publication of record, opinion and news for faculty and staff). We also searched campus photography archives, specifically, external building images. We organized our findings as a historical narrative of major time periods of campus urban forest development.

### Aerial Imagery: 1970–2012

To assess changes in tree cover, we visually interpreted aerial photographs, a technique used in other studies of urban canopy change (Berland 2012; Gillespie et al. 2012; Nowak and Greenfield 2012). We obtained nine aerial images (Table 1), with the earliest image from 1970; we did

**Table 1** Aerial photos used to assess tree cover

Year	Leaf status	Color	Resolution (pixel size, cm)	Source
1970	Partially on	Grayscale	61 <sup>a</sup>	DVRPC
1980	Off	Grayscale	61 <sup>a</sup>	DVRPC
1990	Off	Grayscale	61 <sup>a</sup>	DVRPC
2000	Off	Grayscale	46	DVRPC
2003	Partially on	Grayscale	16 <sup>a</sup>	Penn FRES
2004	Off	Color	15	PASDA
2005	Off	Color	30	PASDA/ DVRPC
2010	Off	Color	9.7	PASDA
2012	On	Color	9.7	PASDA

Images were obtained from the Delaware Valley Regional Planning Commission (DVRPC), University of Pennsylvania Facilities and Real Estate Services (FRES), and the Pennsylvania Spatial Data Clearinghouse (PASDA).

<sup>a</sup> Pixel size for older aeriels are approximate.

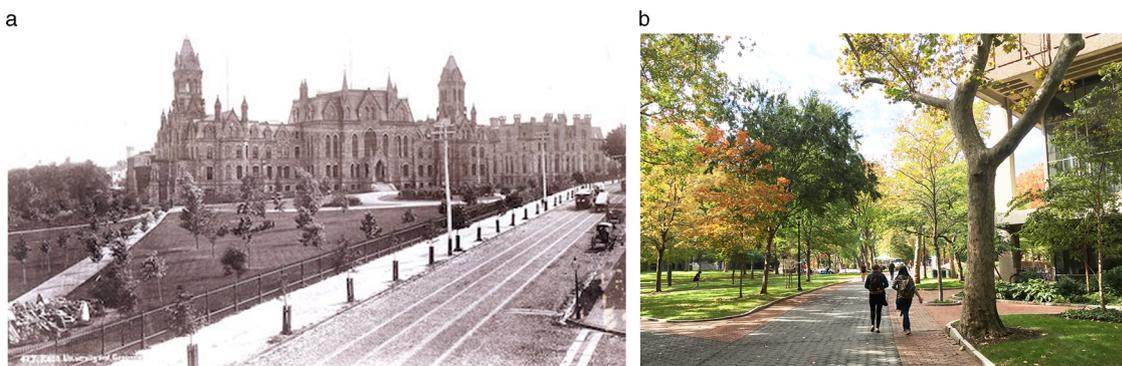
not use earlier images because the resolution and leaf-off imagery made distinguishing trees in a dense urban landscape impractical. We laid 500 random points in the same geographic position for each image year within the expanded campus boundary; 219 of those points fell within the core campus boundary. An interpreter then classified land cover at each point following Nowak and Greenfield (2012). A more experienced interpreter conducted a 10% audit, with 97.4% agreement. We then determined whether tree cover change was statistically significant over the 42-year period, as well as each decade, using the McNemar test, specifically, the `mcnemar.exact` function in the package “`exact2 × 2`” in *R* (Fay 2015; R Core Team 2015).

## Development of Penn’s Urban Forest

### Laying Down Roots: 1870–1897

Penn’s campus was built on land acquired by the City of Philadelphia from the heirs of William Hamilton, an influential horticulturalist (Madsen 1989). From the mid-18th century into the early 19th century, this landscape was a mix of horticulture and agriculture with scattered housing (Long 1991; Wunsch 2004). The land was relatively open without a dense canopy. When the University purchased this site from the City in 1870, it was a mix of municipal buildings, agriculture, and residences (Ellet 1843; Thorpe 1895; Long 1991). In 1876, the West Philadelphia neighborhood near campus was described as “one of the most attractive sections of the city, blending as it does, the beauties of both country and town” (qtd. in Rosenthal 1963, part 7). By the late 19th and early 20th centuries, many streets in this neighborhood were bordered with trees (Miller and Siry 1980).

After Penn acquired its new home, the landscape changed from agricultural and estate fields to a manicured campus. As early as 1876, Trustees minutes reference tree planting (Trustees Minutes 1876). In photographs from the 1880s–1890s, trees are seen in allées in front of College Hall and along Woodland Avenue (Fig. 2). To celebrate Arbor Day in 1896, a scion of the Treaty Elm—under which William Penn, founder of Pennsylvania and Philadelphia, reportedly signed a treaty with the Lenni Lenape tribe—was planted in front of College Hall. The Treaty Elm still stands today and is a source of great pride for the University (Zanky 2013). In remarks by Pennsylvania Governor Daniel Hastings, this planting was framed in terms of broad civic values: the importance of trees for mental rejuvenation, spiritual communion, and sustainability of civilizations. Contemporaneous reforestation efforts in Pennsylvania were also discussed, a cause for which Hastings was a major champion. Hastings closed with a call to action:



**Fig. 2** **a** View facing south to College Hall (center) and Cohen Hall (right, now Logan Hall), showing trees planted along Woodland Ave. and walkways, 1892. Photo courtesy of University of Pennsylvania

Archives and Records Center. **b** Similar view, Woodland Walk, 2016. Photo by C.E. Cerwinka.



**Fig. 3** **a** Hamilton Walk by the John Morgan Building (left), looking west, 1904. Photo courtesy of University of Pennsylvania Archives and Records Center. **b** Similar view, 2016. Photo by C.C. Welsh

...educate the public sentiment to the point where no man will be disposed to cut down a tree that has not reached its mature growth, without making provision to plant one in its stead. Let the township and village improvement societies see to it that every street and every land is lined with shade trees. (Wilkes-Barre Times 1896, 2)

The largest wooded space on campus was also developed during this period: the Botanic Garden (popularly known as the BioPond, now the James G. Kaskey Memorial Park). The Botanic Garden was established in 1894 by John MacFarlane, Professor of Botany, after initial designs by Joseph Rothrock, Chair of the Department of Botany, who is considered the “Father of Forestry in Pennsylvania” (MacFarlane 1899; Wirt 1939; Almanac 1972). Onto this 2.0 ha site (currently 1.2 ha), MacFarlane installed plant houses, beds, ponds, specialty gardens, and an arboretum with 300–400 species of trees and shrubs. Graduate students were required to study plants for a continuous year.

### Street to Walkway Conversions: 1898–1912

The year 1898 marked the development of two pedestrian thoroughfares: Smith Walk and Hamilton Walk. Once a simple footpath (National Park Service 1995), Smith Walk was formalized through installation of a stone path and tree planting in front of the Dental School (now Hayden Hall). Hamilton Walk, in contrast, was created when Pine St. between 36th and 38th Sts. was shut down and removed from the city records in 1898 (Harshberger 1899). After the street was closed, a walking path was installed and planted with trees (Fig. 3). Named for former University Trustee and politician James Hamilton (Trustees Minutes 1899), but later attributed to William Hamilton (James’ nephew), the walkway was described as a “fitting memorial ... for it commemorates in the green, growing things he loved his great service to early American botany and horticulture” (Harshberger 1921, 123). Ellen Harrison, wife of Provost Charles Harrison (1894–1910), was central to the

development of Hamilton Walk and other green spaces. She raised funds and oversaw landscaping (The Philadelphia Inquirer 1910b): “Every tree, shrub and blade of grass that grew on that campus she either planted or supervised and she paid for the lot” (Dallett 1977, 1).

Another garden was created around this time at the Museum of Archaeology and Paleontology (now the Penn Museum of Archaeology and Anthropology), built 1899–1929. Prior to development, the grounds were a “swampy wasteland” and city dump. After development, the garden displayed a global collection of plants in “an eclectic Victorian extravaganza” (Haller 1999, 34). The Penn Museum, combined with the walkways and the Botanic Garden, created a leafy campus whose beauty was lauded as one of the “sights of the city,” with grounds “diversified by terraces, shrubbery, and many different species of trees” (Nitzsche 1906, 1).

### Initial Campus Plans: 1913–1956

Little was done for the campus landscape during this period, which was dominated by the two world wars and the Great Depression, and saw the University enter a tough financial situation, with major refinancing in 1931 (The Philadelphia Inquirer 1931). Yet plans were articulated for landscape modifications to come. In 1913, the first comprehensive campus plan was released, incorporating both building and grounds (Cret et al. 1913; Fig. 4). The plan was led by Professor of Architecture Paul Cret, an internationally renowned architect whose projects included Rittenhouse Square in Philadelphia (Barrata 2002) and the master plan for the University of Texas at Austin (Anderson and Butler 1999). Other designers of the 1913 plan were Warren Laird and the Olmsted Brothers (sons of the eminent landscape architect Frederick Law Olmsted, Sr.). This team identified problems associated with urban development surrounding campus. Although the campus originated in a “semi-rural



**Fig. 4** The 1913 campus plan (Cret et al. 1913), showing proposals for a boulevard by the river and a pedestrian mall north of College Hall. Image courtesy of University of Pennsylvania Archives and Records Center

region traversed by quiet streets and country roads,” there was increasing intrusion of city noise and traffic from trolley cars and the railroad (Cret et al. 1913, 6), as Philadelphia’s population and industry had rapidly expanded. The plan advocated for “the fixed principle of creating new and preserving old open spaces enclosed by buildings and not employed to surround them” (8). The report critiqued the lack of prior planning, and called for creating a pedestrian mall north of College Hall and a riverfront boulevard connecting the campus to municipal parks.

Notably, this plan was created when the University was in the midst of political controversy regarding land development (The Philadelphia Inquirer 1910a). A group of Philadelphia museums sued Penn, alleging that the University was not fulfilling its obligation to create a public park on tracts purchased from the City in 1910 (The Commercial Museum 1916). Cret’s plan was released around the same time that court arguments were heard in 1913, and the University ultimately won on appeal in 1915 at the Pennsylvania Supreme Court. In 1914, World War I began and Cret served in the French army. His campus plan was not implemented. Gardening and landscape care, which had been integral to early campus development, were neglected in the ensuing decades.

The next major plan was released in 1948 by a Trustees committee of Penn architecture alumni, led by Sydney Martin. This plan proposed adding 14.2 ha to the 45.7 ha campus, which would be accomplished by converting several blocks of Locust St. and Woodland Ave. into pedestrian paths (Fig. 5). The Trustees committee stated that “Locust Street, as a wooded walk closed to vehicular traffic, will become the backbone of the proposed plan;” and this new walkway “has every possibility of being dramatic” (The Trustees Committee for the Physical Development of the University of Pennsylvania 1948, 3, 7). President Harold Stassen (1948–1953) called this “a plan for a generation” and said the dramatic changes would make Penn “one of the most beautiful metropolitan campuses in the world” (The Pennsylvania Gazette 1948, 13). Development of these



**Fig. 5** The 1948 campus plan (The Trustees Committee for the Physical Development of the University of Pennsylvania 1948), showing trees lining streets and proposed pedestrian walkways. Image courtesy of University of Pennsylvania Archives and Records Center

walkways began a decade after the Martin plan was released.

### Campus Expansion and Redevelopment: 1957–1975

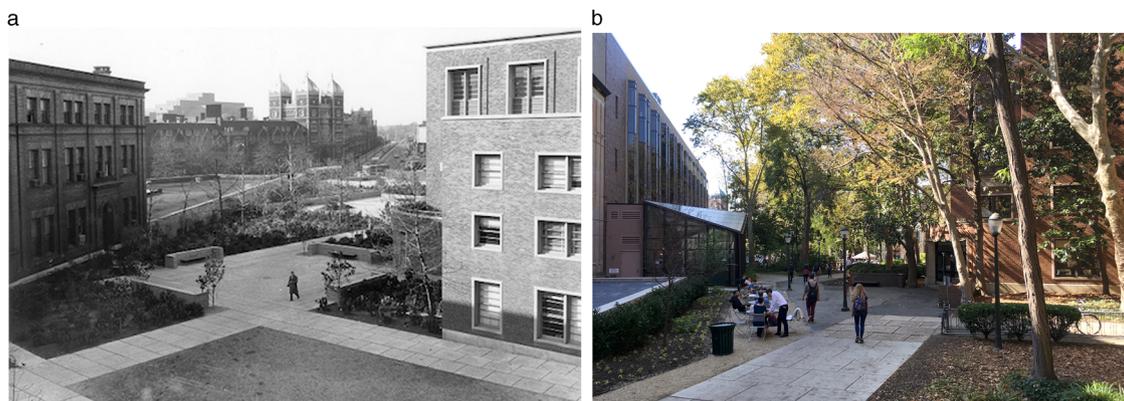
By mid-century, the University and the surrounding neighborhood were rapidly changing. In the wake of the post-World War II GI Bill, Penn positioned itself as a national institution, rather than a regional one, and research funding and enrollment increased substantially, creating a need to expand the physical size of campus (O'Mara 2005; Puckett and Lloyd 2015). The University even considered moving to Valley Forge, a Philadelphia suburb, where the landscape “offered the benefits of education in a pastoral setting” (Puckett and Lloyd 2015, 18). Ultimately, the administration refocused on the city campus. In addition to the 1948 plan, campus expansion was guided by plans in 1961 and 1962 (Puckett and Lloyd 2015), which focused more on buildings than landscaping.

Meanwhile, West Philadelphia was “rapidly turning from a middle- and working-class white to working-class and poor black” neighborhood (O'Mara 2005, 143). Penn expanded its campus through redevelopment and eminent domain, “ripping up whole neighborhoods” (Hughes 1997, 4), including an area locally referred to as Black Bottom (Rodin 2007; Allen and Oswald 2012). The neighborhood surrounding Penn became known as University City, a name invented as a marketing strategy by a local realtor (Hughes 1997). Construction of the University City Science Center, north of campus, was the focus of opposition by black community leaders and student protestors (Glasker 2002; Puckett and Lloyd 2015). Campus expansion came with tremendous impacts to the surrounding community, as homes were razed and residents displaced with the justification of removing so-called blight (Gordon 2003). Redevelopment occurred simultaneously with other tensions at Penn in the 1950s–1970s over racial prejudice, crime, anti-

war protests, and campus policing (Sudow 1999). Reverberations from this time period continue to resonate today with challenges in the university-community relationship (Hughes 1997; Allen and Oswald 2012; Puckett and Lloyd 2015; Rodin 2007).

Penn's expansion was situated within larger patterns of urban renewal and its manifestation in Philadelphia (Adams et al. 1991; Heller 2013). Under the leadership of Edmund Bacon, Executive Director of the City Planning Commission, this included redesign of neighborhoods and transportation construction. Working in close collaboration with the City's politicians and planners (Puckett and Lloyd 2015), Penn administrators initiated a decades-long process of acquiring and demolishing properties, converting streets to walkways and planting trees. Penn transformed “from an institution landlocked by an increasingly congested urban environment to a tree-lined, pedestrian enclave with closed streets and quadrangles, buffered if not fully protected from the encroaching city” (Puckett and Lloyd 2015, 25). The University President during this time, Gaylord Harnwell (1953–70), has been credited with creating the “modern Penn campus” much as it exists today (26).

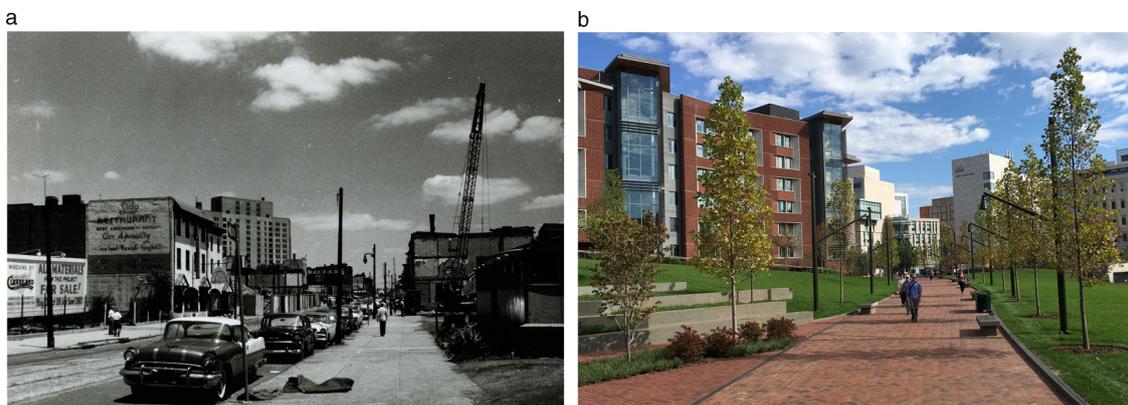
Woodland Avenue was converted to Woodland Walk when the city closed the street and deeded the land to the University in 1957. The avenue had a busy trolley line, and burying this trolley was seen by Penn leadership as critical to a thriving University. Burying the trolley required substantial political cooperation from the City, attributable to decades of lobbying by University leaders and alumni (Puckett and Lloyd 2015). Ian McHarg, Professor of Landscape Architecture who pioneered the integration of ecology and planning (McHarg 1969), designed a series of small parks lining Woodland Walk between 36th and 37th Sts. Completed in 1958, this site was initially referred to as McHarg Gardens (Fig. 6). As the first major planting in this time period, McHarg Gardens “suggested the potential richness of campus” (Thomas and Brownlee 2000, 122).



**Fig. 6** **a** McHarg Gardens along Woodland Walk shortly after installation, facing southwest, 1958. Photo courtesy of University of Pennsylvania Archives and Records Center **b** Similar view, 2016. Photo by C.E. Cerwinka



**Fig. 7** **a** Locust St., looking east on 3600 block, Dietrich Hall on the right and fraternities on the left, c1965. Photo courtesy of University of Pennsylvania Archives and Records Center. **b** Similar view, Locust Walk, 2016. Photo by C.E. Cerwinka



**Fig. 8** **a** Woodland Ave., facing northeast from 34th St., 1957. Photo courtesy of University of Pennsylvania Archives and Records Center. **b** Similar view, Woodland Walk, 2016. Photo by C.E. Cerwinka

Locust Walk between 36th and 40th Sts. was created in stages from the late 1950s through early 1970s (Puckett and Lloyd 2015). This pedestrian mall was designed by George Patton, a prolific practicing landscape architect in Philadelphia and lecturer at Penn who specialized in landscape preservation. Patton's design for Locust Walk built on the historic character of Locust St. by adding geometric pavement patterns, new lighting, and preserving some of the existing trees. Today, this walk "is often mistaken for an original component of the campus when in reality the space is a highly engineered piece of mid-twentieth century landscape architecture" (Bishop 2013, 43). Locust Walk is now an iconic element of the Penn campus (Fig. 7), functioning as a central pathway, a "focal point for student life" (Bishop 2013, 46) and a ceremonial promenade during graduation.

Based on photographic evidence presented here, as well as other photographs in the University archives, some street trees were present on Locust St. and Woodland Ave. prior to conversion to pedestrian paths, but many more trees were planted after conversion (Figs. 6–8). Where homes were demolished between 38th and 40th Sts., high-rise

dormitories surrounded by manicured green space were built (popularly known as the Superblock). However, redevelopment also led to canopy loss, such as the removal of elm trees at the corner of 34th and Walnut Sts., which sparked student protests (Puckett and Lloyd 2015). Additionally, some redeveloped areas became surface parking lots devoid of trees.

Despite localized tree losses, this period created conditions for increased canopy cover in the 1970s and beyond. Tree canopy in the core campus was 8.7% in 1970 and rose to 11.7% in 1980, a growth of 33% (Table 2, 3). In the expanded campus boundary, canopy cover started smaller but increased by a similar proportion (and was statistically significant). By the 1970s, the area referred to as the core campus in this manuscript was set, with lands in the expanded campus boundary acquired over the next few decades (University Archives and Records Center 2016).

#### Landscape Development Plan: 1976–1994

After the mid-century building boom, President Martin Meyerson (1970–1981) inherited a financial crisis of budget

**Table 2** Tree cover on the campus of the University of Philadelphia based on aerial photointerpretation

Year	(n)	Core campus (%)	(n)	Expanded campus (%)
1970	207	8.7	473	5.7
1980	206	11.7	478	7.5
1990	209	16.7	486	10.1
2000	209	18.7	487	10.7
2003	215	19.1	495	10.7
2004	219	20.1	500	12.0
2005	218	20.2	499	12.2
2010	218	21.6	499	12.8
2012	219	20.5	500	12.8

Sample size was reduced for older aerials due to uninterpretable points

**Table 3** Tree cover overall 42-year increase and decadal increases on the campus of the University of Philadelphia

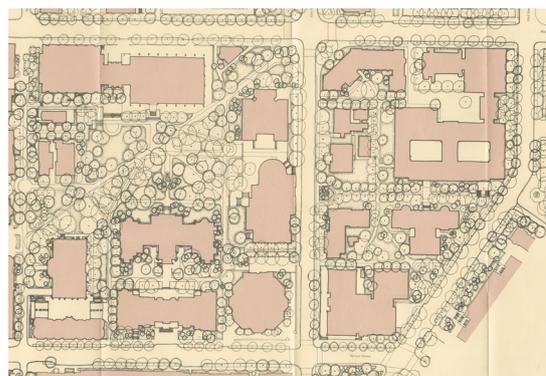
Time period	Core campus (%)	Expanded campus (%)
1970–1980	33	33*
1980–1990	38*	25*
1990–2000	9	4
2000–2010	21	21
1970–2012	144**	122**

For each paired analysis, only points which were interpretable in both years were included

Significant changes were determined with the McNemar exact test (\*  $p < 0.05$ ; \*\*  $p < 0.00001$ )

shortfalls. He spearheaded the Program for the Eighties, an enormous capital campaign which allowed Penn to finally operate in the black (Almanac 1975; Puckett and Lloyd 2015). Notably, Meyerson was also an urban planning scholar.

This set the stage for a new era of campus planning. At the request of Penn's Facilities and Real Estate Services (FRES) office, a campus plan was created by landscape architecture faculty. The 1977 Landscape Development Plan was led by Peter Shepherd, Dean of the Graduate School of Fine Arts (now PennDesign), "whose particular specialty was the forming of urban landscapes" (Thomas and Brownlee 2000, 132), and who also designed other university campuses (Tuset 2014). Faculty members Laurie Olin, Robert Hannah, Carol Franklin, Colin Franklin, Narendra Juneja, Rolf Sauer, and Leslie Sauer were also involved with the 1977 plan, under the Center for Environmental Design (CED), which was created to work on the campus landscape. The 1977 plan harkened back to the 1913 plan, because "the main thrust of the report—to establish an organic network of open space—was ignored" (CED 1977, 13). Using McHarg's layering method of data analysis (which provided the conceptual underpinnings of Geographic Information Systems; Daniels 2009),

**Fig. 9** Proposal in the 1977 Landscape Development Plan (CED 1977) for the area between Walnut and Spruce Sts., and between 36th and 33rd Sts., which includes Blanche Levy Park (also known as College Green). Both existing trees (single line) and proposed new trees (double line, appears thicker) are shown. Image courtesy of University of Pennsylvania Archives and Records Center

Shepherd and colleagues identified problem areas. These problems included buildings that opened to the interior pedestrian paths, which closed the campus off from connections to the city (as was the original intent; CED 1977; Puckett and Lloyd 2015), unattractive parking lots, and areas prone to flooding. The plan highlighted tree losses in the preceding decades due to Dutch elm disease, building construction, and lack of maintenance. The faculty wrote a scathing indictment of the campus condition in the 1970s:

... the landscape of the University had suffered. The great landscape works of the 1890s and early 1900s had matured, with many once magnificent trees now diseased or dying. No major replanting efforts had been undertaken to recapture this great exterior canopy... Furthermore, barring a few exceptions, no major landscape works had been undertaken. The unique character of the campus that had made it one of the 'sights of the city' was now but a remnant of what was, with buildings and large areas of pavement ... constructed in total disregard of this character, yielding a landscape of disjointed pieces, with a lack of feeling and warmth, with all the spaces in between left to decay. (CED 1977, 16)

This report laid out landscape planning principles and proposed detailed design solutions, such as making campus entryways and main pedestrian paths more inviting by adding trees and shrubs, as well as enhancements to small and large open spaces, with plant species suggestions for different types of spaces. A key information source was the first campus tree inventory, begun in 1976 by Ann Rhoads, botanist at the Morris Arboretum and Adjunct Professor of Botany. The plan illustrated the presence of existing trees and proposed new trees (Fig. 9). Construction of the first phase began in 1978 with the redesign of College Green

(renamed Blanche Levy Park; Almanac 1978), led by the CED. This construction was funded by the aforementioned capital campaign (Puckett and Lloyd 2015). Over the ensuing decades, firms run by Penn faculty designed many other campus green spaces (Popp 2007).

The 1977 plan has influenced all subsequent campus landscape projects and led to the creation of the University Landscape Architect position (University of Pennsylvania FRES 2016a). A 1988 Campus Master Plan called for a continuation of planting efforts, with specific needs to enhance green space in the Superblock and a stronger system of open spaces (Almanac 1988). The Botanic Garden did not get a site design treatment in the 1977 plan, although the report noted its specific role in botanical education. In 1983, the Botany Club initiated a revival of the garden (Almanac 1983).

Increased attention to the planted landscape during this period supported continued canopy growth, with a 38% increase in canopy on the core campus from 1980–1990 (Table 2). Canopy change was statistically significant for both the core and expanded campus during this decade (Table 3).

### Community Greening and Sustainability: 1995–2017

In the 1990s and early 2000s, Penn's tree management increasingly intersected with adjacent communities and sustainability concerns. In 1998, University City Green (UC Green) was formed through FRES "to unite community organizations, city agencies, university students, and residents in local greening efforts" (Rodin 2007, 76). This extended the University's tree planting beyond campus, reflecting President Judith Rodin's (1994–2004) efforts to invest in West Philadelphia and improve university-community relationships. UC Green's first director, Esaul Sanchez, had also spearheaded UC Brite, a program to add more street lights to the neighborhood, initiated in response to a student murder near campus (Rodin 2007). After the terrorist attacks of September 11, 2001, a memorial planting demonstrated UC Green's efforts to promote neighborhood cohesion by bringing together people of different races and religions to promote healing (Sanchez 2013). In 2004, UC Green became an independent nonprofit. The organization strove to "green with the community" rather than "for the community" (Hardy 2008, 4), exemplified by the UC Green Corps, a jobs program for local high school students. The UC Green Corps and extensive volunteer stewardship have resulted in neighborhood tree plantings with very high survival (Roman et al. 2015). A long-time West Philadelphia resident, Winnie Harris, ran the UC Green Corps, and was also the volunteer coordinator and recent acting executive director. She was a well-respected community organizer and gardening enthusiast, described by a neighbor

as a "pillar in this community" (Shaw 2017). In a separate program, Penn distributed trees to staff for planting at their homes through the Creating Canopy initiative, begun in 2011, a partnership with Philadelphia Parks and Recreation (McWilliams 2012).

The University acquired new lands to the east in 2007: 6 ha of former US Postal Service property along the river (Weightman 2013). Landscape management during this time also related to campus sustainability plans, such as the Climate Action Plans of 2009 and 2014 (University of Pennsylvania 2009; University of Pennsylvania 2014; University of Pennsylvania 2016). New parks that opened 2011–2013 in the eastern part of campus (Kane Park, Penn Park, and Shoemaker Green) increased the amount of campus green space by 30% while promoting sustainable landscapes (Weightman 2013). For example, Shoemaker Green converted aging tennis courts into a green space for stormwater management, with rain gardens, tree trenches, and porous pavers, while also providing space for outdoor teaching and events (Almanac 2010a).

Meanwhile, numerous planting projects occurred within the older parts of the core campus. In 2001, the Botanic Garden was renamed and renovated with a new endowment. Other examples of projects with dedicated funding in the early 2000s include the Class of 1942 Garden at the Kelly Writer's House (Almanac 2003) and the Class of 1957 Geology Garden (Johnson 2015).

Campus tree management during this period was facilitated by new data and arboricultural expertise. The tree inventory was updated in 1995 by the Davey Tree Expert Company, in 2003–2004 by the Morris Arboretum, in 2012 by campus facilities staff, and in 2015 by an urban forestry intern from the Morris Arboretum (Bassett 2015). The 2015 inventory is the most comprehensive in terms of tree measurements collected, and it was used to estimate the ecosystem services of campus trees. Information about campus green spaces was also cataloged for the Penn Plant Explorer website, launched in 2015 (University of Pennsylvania FRES 2016b). With this online map, the public can learn about the history of campus green spaces and their cultural, aesthetic, and environmental benefits. Important to many of these developments have been the staff at the Morris Arboretum, where a Center for Urban Forestry was established in 1991 (Janda 1995). The Arboretum currently offers professional development courses through its School of Arboriculture.

Penn's recent efforts to steward its trees and open spaces have been professionally acknowledged. Shoemaker Green is recognized through the Sustainable Sites initiative, a national certification system (Almanac 2010b). In 2009, Penn earned its first Tree Campus USA designation from the Arbor Day Foundation, and has received this designation annually since (Almanac 2016). As of 2017, the campus is officially recognized as an arboretum (University

of Pennsylvania FRES 2017). Currently, planning, management and maintenance of vegetation on Penn's campus is overseen by the University Landscape Architect, Landscape Planner and Urban Park department, who work with various other University grounds crews, gardeners, horticulturalists, arborists, and designers, as well as external contractors.

Canopy cover on the core campus grew to 20.5% in 2012, and 12.8% on the expanded campus. Overall, from 1970–2012, tree canopy expanded by 144% on the core campus and 122% on the expanded campus. This change was statistically significant (Tables 2, 3).

## Discussion

Today's tree canopy on Penn's campus has been a century and a half in the making. In this discussion, we address the generational time scales and systematic management necessary for increasing tree canopy; the connections between trees, wealth, and prestige; the urban forest legacies of local scholars; the campus as a microcosm of larger movements in urban planning; and making room for trees in dense urban landscapes.

### Generational Time Scales and Systematic Management

The Penn story demonstrates that several decades are needed to fully realize ambitious plans to increase the extent of the urban forest. Visualizations in the 1948 and 1977 plans show a leafy campus which came to fruition in the early 2000s, as tree cover on the core campus exceeded 20% for the first time. Indeed, University President Stassen explicitly acknowledged the generational time scales needed for realizing change when the 1948 plan was released (The Pennsylvania Gazette 1948). Such long-term visions are well-suited to college campuses, as articulated by the former President of the University of Oklahoma:

The act of tree planting symbolizes the university's high academic mission, for both education and tree planting imply vision and delayed gratification. Operating an institution of higher learning is like planting an oak tree which gives shade to people who come along generations later. (qtd. in Gumprecht 2007, 97)

This concept of delayed gratification is also central to sustainability planning (Arbuthnott 2010). Indeed, municipal sustainability plans and urban forest master plans tend to project several decades forward (e.g., City of New York 2012; City of Toronto 2012; City of Philadelphia 2015; Tree Pittsburgh 2012). Decadal time scales also reflect the temporal horizon of municipal comprehensive plans, which

typically extend 20–30 years into the future (Hack et al. 2009).

Sustainable management has also been applied to urban forestry. On a manicured site such as Penn's campus, “[s]ustainable urban forests require human intervention” (Clark et al. 1997, 20). Ongoing care is needed to support urban forests through intentional planting in lieu of natural regeneration. One management strategy employed by arborists is to maintain a mix of tree ages, as this allows for consistent urban forest structure in the face of population cycles of tree planting, growth, death and removal (McPherson and Kotow 2013). The importance of mixed tree age classes was raised in Penn's 1977 plan for the College Green, albeit with motivations for both aesthetics and maintaining consistent canopy cover (CED 1977). The idea of purposefully managing tree population cycles to sustain forest cover also harkens back to the Pennsylvania governor's remarks at the Treaty Elm planting ceremony, in which he stressed the importance of replacing trees that have been removed (Wilkes–Barre Times 1896). Olin later extended the concept of forest population dynamics as a metaphor for landscape change in the city itself (Popp 2007). Both the city as a whole and the urban forest within it are dynamic, ever-changing systems. To manage tree population cycles and grow canopy cover on Penn's campus—or in any city—over the long term, continuous human intervention is essential (Roman 2014).

Generational time scales relate not only to the biophysical reality of growing trees, but also to the institutional and financial commitments necessary to care for them. Long-term continuity in urban forest management is challenging for municipal forestry programs, for several reasons. Major initiatives in large cities often originate with mayors (Lawrence and McPherson 2013) and are therefore only feasible if successive mayors take up the banner of their predecessors' plans. For example, in New York City, New York, Mayor de Blasio completed the Million Trees NYC initiative which was launched by Mayor Bloomberg (Foderaro 2015), whereas Denver, Colorado cut back its Mile High Million campaign when a new mayor took office (Meyer 2013). Similarly, because urban forest master plans and tree cover goals extend across many decades, their implementation requires support from different administrations.

Long-term planning and management can also be challenging for municipal arborists because they are often narrowly focused on emergency response, such as tree removals following storm events or due to pest outbreaks. Urban foresters distinguish between systematic management, defined as “a planned approach taken with scheduled tree care”, and reactive management that “occurs on-demand as the result of a crisis or unplanned event” (Hauer and Peterson 2016, 58). In a recent survey of municipal forestry

programs across the US, only half described their operations as systematic. Furthermore, only half of the programs had strategic plans concerning trees and green spaces (Hauer and Peterson 2016). The widespread lack of strategic plans and systematic approaches indicates that many cities are not approaching sustainable urban forest management through the lens of generational time scales. Indeed, even when plans are in place, they may not have detailed guidelines for implementation (Gibbons 2014). Additionally, urban foresters have expressed wide gaps between practices they think are important (e.g., having a tree inventory, conducting annual inspections) and practices they actually carry out (Elmendorf et al. 2003). This gap may be explained, in part, by lack of funding, as many urban foresters think that their programs have inadequate budgets (Elmendorf et al. 2003, Hauer and Peterson 2016). Ongoing financial support is essential to sustainable urban forest management (Clark et al. 1997, Elmendorf et al. 2003). Yet beyond total budget amounts, financial sustainability also means diversified funding sources as well as appropriate allocations for short- and long-term needs (Hauer and Peterson 2016; Nguyen et al. 2017).

Penn's large endowment and elite Ivy League donors provide the campus with resources that are not available to many municipalities, and the landscape enhancements serve as symbols of prestige, as we discuss further in the next section. While this campus' story may not be directly transferable to city foresters, the insights into time scale and continuity factors are relevant to any urban forestry program. The history of Penn's urban forest demonstrates that tremendous landscape changes are possible when long-term financial and institutional support materialize after an extended period of neglect. In the 1977 Landscape Development Plan, Shepherd and colleagues noted that while the campus expanded mid-century, with many new buildings constructed, "no money was spent on renewing the old landscapes between them" (CED 1977, 5). Anticipating resistance from faculty, they asserted that new investments were "simply arrears of money that should have been spent before" (CED 1977, 6). They concluded their report with a call for professional horticultural staff. Importantly, the plan led to the creation of the first University Landscape Architect position (University of Pennsylvania FRES 2016a); no comparable position had previously existed at the University, even during the heyday of tree planting in the late 19th century. Furthermore, the plan suggested prioritized phases for implementation as funding became available (CED 1977). Crucially, this plan was released as the University achieved financial stability in the 1970s under President Meyerson (Puckett and Lloyd 2015). Over the ensuing decades, recommitment to landscape management in campus plans and targeted fundraising allowed the 1977 plan's vision to

slowly become reality, as various sites were enhanced in a piecemeal fashion.

### Trees, Wealth, and Prestige

Wealth, prestige, and power have long been connected with urban forests. Indeed, power is considered one of the principle drivers of urban forest historical development (Lawrence 2006), and garden and landscape design have long been used to indicate status and wealth (Rogers 2001). The story of Penn's urban forest reflects these forces, as the 1977 Landscape Development Plan asserted that due to the deteriorated landscape, "Penn's image at present is tarnished" (CED 1977, 5), lamenting that "the very life, fabric, and identity of the campus was being lost" (CED 1977, 17). The enhanced landscape came to symbolize Penn's growing stature as a research institution. George Thomas, Professor of Historic Preservation and Urban Studies, reflected that investing money into landscape design was not popular with faculty at first, but this changed as student applications spiked:

Penn suddenly realized that they were selling an experience, they were selling a visual representation of their value. And in my mind, this was the real step that pushed Penn from a solid, first-rate university into a top-tier university. (qtd. in Popp 2007, 2)

Other literature about college campuses has similarly associated campus appearance and perceived academic prestige, with many students deciding where to apply based on their immediate impressions during campus tours (Gumprecht 2007; Waite 2014).

In municipal forestry, the link between prestige, wealth and trees manifests in spatial patterns. Contemporary urban tree cover is closely associated with socioeconomic status and lifestyle (Grove et al. 2014; Schwarz et al. 2015), and tree planting programs can disproportionately serve affluent neighborhoods (Donovan and Mills 2014; Locke and Grove 2015). Indeed, urban trees can be viewed as a commodity, making the unevenness of tree cover an environmental injustice (Heynen 2003). Local actors may exacerbate these patterns (Conway et al. 2011). Universities may be important local actors in urban forestry, as they engage in tree planting activities within and beyond campus, while they also play critical roles in local economies (Birch et al. 2013), sometimes wield considerable socio-political power, and have faculty and alumni that can inform urban planning and design.

Relating this back to Penn's campus, the landscaping activities in the late 20th century express different facets of power and privilege for university-community relationships. Importantly, as Locust Walk was constructed during the 1950s–70s, the buildings lining the pedestrian path were

purposefully oriented inward, to “truly separate the campus from its deteriorating surroundings” (CED 1977, 14). The street sides of the new buildings had unattractive service drives. Tree planting along Locust Walk and Woodland Walk could therefore be seen as a gesture that physically and symbolically dissociated Penn from West Philadelphia, tying into the heightened racial tensions during this period (Sudow 1999; Allen and Oswald 2012). In a critical review of Penn’s expansion during this time, a local reporter remarked that, “As Penn’s campus grew more splendid, it became an island of privilege in a sea of poverty” (Saffron 2015, 1). The role of urban universities during the urban renewal era has been described as deeply problematic for surrounding neighborhoods, with some universities assuming “the assigned role of redeveloper as license to harvest as much land as they could for their own use while ignoring the needs and desires of the community” (Keefer 2013). While there are varied perspectives on the current and historic role Penn has played in West Philadelphia (Hughes 1997, Sudow 1999, Allen and Oswald 2012, Puckett and Lloyd 2015), these quotes speak to the tough critiques that have been made about power and privilege in campus expansion.

While the 1977 Landscape Development Plan did not directly address the racial tensions and social consequences of land acquisition, Shephard and colleagues were very critical of the inward building orientation, and alluded briefly to the problems of urban renewal and campus security:

By 1968, with anti-war demonstrations and general student unrest, the idea of closing off the campus began to be taken literally, with some even proposing a series of campus gates to control potential unruly situations. The initial planning idea, therefore, of strengthening the campus pedestrian spine had become transformed into a policy of turning the University’s back to the city. (CED 1977, 16)

Indeed, other urban universities used their gates for policing during this period; for instance, the gates at Columbia University in New York City were guarded against protests by black students and neighbors (Bradley 2009; Sutton 2017). Many universities had long ago erected barriers such as walls and gates to separate themselves from the city and preserve pastoral landscape ideals (Guilbert 1995; Severino 1995). Yet Shephard and colleagues took their plan in a markedly different direction, advocating for better transitions between Penn and its surrounding community through landscape design, with inviting entrances made of greenery rather than literal gates (CED 1977).

Although the 1977 plan, and the many decades of planting projects that followed, smoothed over the physical dissociation of the campus with the surrounding

neighborhood, the underlying tensions with the neighborhood remained (Hughes 1977; Allen and Oswald 2012; Puckett and Lloyd 2015). Penn has since attempted to amend its relationship with West Philadelphia, initiating a major push for community partnerships and engagement under President Rodin in the 1990s and early 2000s. The University embarked on an Urban Agenda to “reaffirm urbanism as a critical feature of American life” and show that Penn was a good neighbor (The Pennsylvania Gazette 2004, 4). Notably, Rodin grew up in Philadelphia, attended public schools, and was an undergraduate at Penn on scholarship (O’Neill 1994). Rodin recognized that West Philadelphia residents had valid reasons to distrust and resent the University: “Residents by and large felt that Penn had turned its back on the neighborhood. Who could blame them? Penn was so near and loomed large, yet felt so remote” (Rodin 2007, 4). Her administration also oversaw the purchasing of non-residential lands east and south of campus, and committed to revitalization to the west and north without buying new land there; this was part of the Penn’s commitment to “doing better” (qtd. in Katz 1996) compared to the urban renewal era.

The establishment of UC Green was one expression of multi-faceted efforts by Penn to engage with the local community in West Philadelphia in the late 1990s (The Pennsylvania Gazette 2004; Rodin 2007). Yet this kind of urban revitalization through greening is not without critics. As the neighborhood surrounding Penn has gentrified in recent years (Ehlenz 2015), tree planting could be perceived as part of a larger process to make West Philadelphia a more attractive place to live and work for faculty, staff, and students, which in turn may displace long-time residents. Yet other University decisions likely played more direct roles in gentrification, such as the creation of a Penn-administered public school as well as a mortgage assistance program for faculty and staff (Ehlenz 2015). Furthermore, ecological gentrification is a contested area of scholarship, with varying perspectives on equity dimensions of urban greening initiatives depending on the characteristics of the neighborhood and the inclusivity of the program (Wolch et al. 2014). UC Green’s efforts to “green with the community” rather than “for the community” (Hardy 2008, 4) suggest an intention to foster inclusivity with residents. As the first director of UC Green asserted, “There’s something magical about gardening... It allows people to overcome the barriers and difficulties of working together as a community” (qtd. in Hanco 1999). Urban forestry scholars have likewise indicated that community tree planting can strengthen social ties and deepen civic engagement (Campbell 2015, Fisher et al. 2015). Further research is needed to understand how university-originated neighborhood greening initiatives impact local communities, particularly where there are deeply entrenched town-gown divisions.

Future studies could also explore the potential differences in campus greening histories across universities with varying levels of wealth. Within Philadelphia, for example, the campuses of Drexel University and Temple University also underwent major expansions during the urban renewal period (Strom 2005; Keefer 2013); their campus and neighborhood tree canopy changes could be compared to Penn's. Similarly, new research could compare urban forest development histories at elite universities in other cities, to explore how their tree planting initiatives on and off campus may (or may not) relate to prestige, faculty expertise, and neighborhood change.

### The Legacy of Local Scholars

The development of Penn's urban forest has been influenced by the community of scholars at the University and throughout Philadelphia. These faculty and alumni were key actors in the growth of campus canopy, and they brought to bear their nationally and internationally renowned expertise to transform the landscape. With early campus development, not only did Penn have respected botany faculty such as MacFarlane and Rothrock, but Philadelphia was also a leading center for botany and horticulture. Indeed, Penn's campus is located on the land of one of America's most prominent early horticulturalists, William Hamilton. MacFarlane, Rothrock, and Provost Harrison's wife were active members of local botanical and horticultural societies, and the Provost was honorary president of the Botanical Society of Pennsylvania (University of Pennsylvania 1898; Harshberger 1899; Boyd 1929). MacFarlane and Mrs. Harrison were also advocates for other local causes, such as the restoration of Bartram's Garden, "the oldest surviving botanic garden" in the US (National Park Service 2002, 1). Later, as the University reinvested in trees with the 1977 plan, local botanists were again essential actors with the first campus tree inventory. Updates to that inventory and other consultations with staff at the Morris Arboretum have helped to preserve existing trees and strategize for new plantings.

Penn's leading faculty and alumni in landscape architecture and urban design likewise played critical roles in the growth of the campus canopy, and the University has been a leading institution in landscape architecture for over 100 years (Weller and Talarowski 2013). From proposing unified campus plans and design principles to developing specific green spaces, these scholars—including Cret, Patton, McHarg, Shephard, and others from the CED—literally reshaped the campus. Both the unrealized 1913 plan and the enormously successful 1977 plan emphasized comprehensive planning that integrated green spaces with the built environment, enhancing individual elements to

create a cohesive whole. The 1977 plan also reflected the aesthetic ideals depicted by Turner (1984):

On the one hand, a campus is essentially a quiet, pastoral setting, removed from the pressures of the city and everyday life, a haven in which one can restore oneself and gain a fresh perspective on the surrounding world and flow of events. On the other hand, a large campus becomes itself a city, an ideal of city and communal life... (CED 1977, 29)

A sylvan experience was central to this vision, and indeed, Penn's campus is highlighted in Turner's (1984) writing about the American campus landscape. Tree planting and maintenance in the late 20th century, and the tremendous increase in canopy cover, are a lasting testament to the bold visions embodied in the 1977 plan, and the expertise of the designers and managers who made those visions a reality. In effect, local scholars were treating Penn's grounds as a landscape on which they could implement their larger ideas about botanical spaces and leafy urban enclaves, much in the same tradition that arboricultural researchers treat the campus as an experimental landscape.

### The Campus as a Microcosm of Urban Planning History

The aforementioned actors were operating within larger trends that impacted the urban forests of Philadelphia and many other US cities. We highlight connections to four broad movements: urban parks; City Beautiful; "the spaces in between;" and urban sustainability.

#### *Urban parks*

Early tree planting and management activities on Penn's campus in the 1880s–1890s occurred as urban greening efforts were gaining prominence nationwide (Eisenman 2016). Indeed, prior to the mid-19th century, trees and vegetation were not common elements in the public realm of American cities (Campanella 2003; Lawrence 2006). But in response to the disadvantages of industrial urbanization, reform-minded leaders led an urban parks movement to address concerns for human health and a desire for natural recreation areas (Schuyler 1986; Stroud 2015). The Fairmount Park system in Philadelphia—one of the largest urban park systems in the world—was developed in the late 19th and early 20th centuries with these motivations in mind (Armstrong 2012). Consistent with contemporaneous trends, remarks by the Pennsylvania Governor at the Treaty Elm planting ceremony in 1896 emphasized the human health benefits of trees. State-level connections to early campus tree planting run deeper, as the professor who originally proposed the creation of the Botanic Garden,

Rothrock, was a leader in statewide reforestation (Wirt 1939). Aligning with the role of urban college campuses as public green spaces, and the growing desire for city parks at the end of the 19th century, botany faculty advocated for alumni to invest in and protect Penn's Botanic Garden as a free amenity (MacFarlane 1899).

### *City beautiful*

At the start of the 20th century, there was a bloom of civic improvement and beautification via tree planting, expressed in the tree-lined boulevards that were a key element of the City Beautiful movement (Wilson 1994). During this period in Philadelphia, Roosevelt Boulevard was designed as a parkway connecting parks to new neighborhoods (Armstrong 2012), while the monumental tree-lined Benjamin Franklin Parkway (based on initial plans by Cret) drew inspiration from the Champs-Élysées in Paris, France (Brownlee 1989). By the early 1900s, American cities were characterized by “an immense arboreal landscape” (Lawrence 2006, 247), and Philadelphia was heavily invested in street tree management (Fairmount 1913). Penn's first tree-lined walkways were emblematic of this trend, as were the open space plantings that collectively created a sylvan landscape and one of the “sights of the city” (Nitzche 1906).

The Smith Walk–Hamilton Walk–Botanic Gardens complex, which emerged ad hoc from the advocacy and fundraising of actors such as MacFarlane and Mrs. Harrison (i.e., not from a cohesive plan), clearly expresses City Beautiful ideals. The 1913 campus plan would have furthered this aesthetic vision and although it did not come to fruition—seemingly due to political controversy, Cret's absence during World War I, and lack of financial resources—its core principles influenced the 1977 plan. The first green spaces and walkways at Penn created the foundational layout of the campus landscape that endures today, in much the same way that park creation and street tree plantings transformed the physical fabric of US cities during that period (Eisenman 2016).

### *“The spaces in between”*

The problems of mid-20th century urban renewal had a substantial influence on the scholarship and practice of urban planning and design in the late 20th century (Alschuler 2009). As previously discussed, in the 1977 plan, Shephard and colleagues critiqued urban renewal and called for reconnecting Penn's campus to the fabric of the city. They argued that the landscapes between buildings were just as essential as the buildings themselves, remarking that “all the spaces in between [were] left to decay” (CED 1977, 16). This perspective was central to Shephard's design approach, which has been described as

“landscape functionalism” (Tuset 2014, 150). In this approach, the landscape architect decides “what to do with the vacant land areas forgotten by urbanism” (Tuset 2014, 152). Similarly, Patton embraced his practical role to “take care of the leftover bits and pieces” (qtd. in Bishop 2013, 33). Olin's work has similarly been described as functional and practical, centered on creating livable landscapes in local contexts (Popp 2007). These landscape architects pushed back against an urban renewal that was more narrowly focused on buildings and infrastructure, and they advocated for a deeper appreciation of the landscape as a human experience, with trees as a fundamental element of vibrant cities. These Penn designers—Patton, Shephard and Olin—brought a pragmatic, problem-solving approach that embraced the additive impact of numerous landscape alterations at varying scales to form a cohesive whole, resulting in a leafy pedestrian-friendly campus.

These reactions within Penn's campus to the challenges of urban renewal and its resulting “disjointed pieces” (CED 1977, 16) relate to larger trends in urban planning. From the 1960s onwards, municipal park departments responded to pervasive urban decline by adopting what Cranz (1982) describes as the “open space” model where “anything goes”: bits and pieces of the city saved from fates of construction, and fluid perimeters where parks flow into the city and the city into the parks. One of the hallmark landscape designs from this period was Paley Park, a pocket park in New York City, which opened in 1967. This privately owned public space, covering a mere 0.04 ha, provides a tranquil oasis in a crowded metropolis, using tree shade and a waterfall to create a calming environment (Tate 2001). This park is a “commendable example of how small, leftover sites in the city can be transformed into viable public spaces” (Tranik 1986, 85). The many small green spaces on Penn's campus are somewhat akin to a series of pocket parks. Additionally, if we view the Penn campus as a park-like space, Cranz's comments about fluid perimeters also resonate, given the emphasis in the 1977 plan on reconnecting the campus to the city (CED 1977). These design strategies to create fluid perimeters and new green spaces out of leftover bits of land were being implemented in cities across the US.

### *Urban sustainability*

Sustainability initiatives emerged in municipal governance in the 1990s and early 21st century, building upon international trends to promote sustainable development as well as renewed interest from municipalities in regional planning (Wheeler 2000). As discussed in the introduction, college campuses are likewise promoting sustainability, and both municipalities and campuses have included tree planting and management in their sustainability agendas (Koester et al. 2006; Young and McPherson 2013). At Penn, the

2014 Climate Action Plan highlighted newly created park spaces as evidence of progress towards sustainability goals, and noted the importance of preserving the integrity of the campus urban forest (University of Pennsylvania 2014). The management of and discourse about trees at Penn during this time period are therefore well aligned with broader municipal governance movements supporting sustainable cities.

### Making Room for Trees

Urban design and reimagined streetscapes are fundamental to realizing canopy cover increases in old, densely built environments such as Penn's campus, as well as old neighborhoods in many cities. For example, in 2008 Philadelphia had a city-wide canopy cover of 20%, with less than 8% in some census tracts (O'Neil-Dunne 2011). The City aims to raise that figure to 30% across all neighborhoods by 2025 (City of Philadelphia 2009). The goal to increase tree cover across all neighborhoods is significant, as it signals a commitment to equity which has been borne out with relatively evenly distributed trees through a yard tree giveaway program (Nguyen et al. 2017). However, attached houses in many areas of the city have little to no yard space; therefore making substantial room for trees to meet the 30% goal would require fundamentally reorganizing the landscape, and planting in areas that are currently impervious surface. Philadelphia is already converting impervious surfaces to vegetated spaces to improve storm-water management (City of Philadelphia 2011). While closing down entire streets—as Penn did—may not be feasible or advisable in many urban settings, cities are nevertheless pursuing related solutions, such as narrowing streets, adding vegetated bump-outs, reducing parking spaces, restructuring traffic circles, (MacDonald 2007; Polanski 2015). Tree canopy can also be added through the creation of pocket parks and gardens. In other words, increasing canopy cover is more than a matter of planting in empty tree pits and lawns; it also involves making room for trees in the first place: creatively inserting vegetation into the built environment.

However, even with substantial financial, professional, and political resources, Penn's campus—which is less densely built than much of the city—is far from meeting Philadelphia's 30% canopy cover goal. This suggests that locally appropriate tree cover targets need to incorporate not only biophysical analyses of potential landscapes for new canopy, but also economic, political, and cultural viability. Indeed, in some urban neighborhoods, residents may not actually want trees (Battaglia et al. 2014). Contemporary messaging about tree benefits from planting initiatives centered on ecosystem services (Silvera Seamens 2013) may not align with resident perceptions and values, such as

aesthetic preferences (Locke et al. 2015) and cultural heritage (Jones et al. 2012). It is worth noting that the increase in tree cover on Penn's campus arose from concerns about the deteriorating and unattractive landscape, and investments were justified with language centered on aesthetics, livable urban spaces, and the academic stature of the University, rather than biophysical goals. As such, trees were selected and sited using a design logic premised on human experience. Moreover, to implement urban tree planting campaigns that are genuinely equitable and inclusive, diverse perspectives from community members are integral throughout the process, so that urban greening and sustainability plans explicitly incorporate environmental justice (Pearsall and Pierce 2010).

### Conclusions

We have found a rich and layered history of urban forest development on Penn's campus. Using an urban college campus as a laboratory for investigating urban forest change, we showed how key actors—and the broader movements in which they operated—were essential to catalyzing the creation of green spaces on this landscape in different eras. Understanding how Penn's tree cover came to exist as it does today required a long view of landscape history. Using mixed methods, we analyzed both the extent of change and the principle mechanisms behind that change. The methods we applied to this small geographic space could be extended to neighborhood or municipal scales to delineate periods of urban forest development in different places and link those periods to quantified changes in tree canopy. Urban forest development may take different trajectories in colleges, neighborhoods, and cities with different financial resources, local expertise, and urban landscape contexts. While the urban forest history on Penn's campus does not directly translate to neighborhood and municipal-level planning—especially considering the wealth, professional skill, institutional structure, and political clout of the University—there are nonetheless elements of this history that are applicable to the city scale. In particular, when establishing and pursuing locally appropriate canopy cover goals, cities should bear in mind that generational time scales and sustained institutional commitments are necessary. Furthermore, landscape design was fundamental to realizing canopy cover increases on Penn's campus, and visionary urban planning and design will be just as critical for municipalities that wish to increase canopy cover.

**Acknowledgements** At Penn, we thank D Garofalo and D Hollenberg of FRES for supporting this research and funding JP Fristensky and CC Welsh. JP Fristensky was also sponsored by the US Forest

Service Philadelphia Field Station. We thank MF Lloyd, TH Horning, JM Duffin, and JJ Ahern for guiding us through the campus archives. We thank G McNichol from the Delaware Valley Regional Planning Commission for sharing aerial photography. Helpful comments on earlier versions of the manuscript were provided by R Weller, MF Lloyd, S Willig, H Pearsall, and two anonymous reviewers.

### Compliance with ethical standards

**Conflict of interest** The authors declare that they have no competing interests.

## References

- Adams C, Bartelt D, Elesh D et al. (1991) Philadelphia: Neighborhoods, division, and conflict in a postindustrial city. Temple University Press, Philadelphia, PA
- Allen K, Oswald M (2012) Powelton Village: University expansion destroyed a neighborhood. Philadelphia Neighborhoods, A publication of Temple University's Multimedia Urban Reporting Lab. <https://philadelphianeighborhoods.com/2012/12/04/powelton-village-university-expansion-destroys-a-community>. Accessed 15 Sep 2016
- Almanac (1972) Unexpected pleasures of Penn: I. The Botanical Garden. University of Pennsylvania Almanac 19(1): 11 July 1972
- Almanac (1975) Program for the eighties. Univ Pa Alm 22(7):1–3
- Almanac (1978) Construction to begin on Blanche Levy Park. Univ Pa Alm 24(19):1
- Almanac (1983) Reviving the biology pond. Univ Pa Alm 29(28):3
- Almanac (1988) A master plan for the campus. Univ Pa Alm 34(34): II–XVI. supplement
- Almanac (2003) Class of 1942 Garden at Kelly Writers House. Univ Pa Alm 50(3):23. September 2013
- Almanac (2010a) Design of Shoemaker Green. Univ Pa Alm 57(11):1
- Almanac (2010b) Shoemaker Green: The red and blue turn grey into a green sustainable site. Univ Pa Alm 57(1):16
- Almanac (2016) Penn's Tree Campus USA celebration. Univ Pa Alm 62(27):6
- Alschuler KB (2009) From urban renewal to regeneration. In: Hack G, Birch EL, Sedway PH, Silver MJ eds Local planning: Contemporary principles and practices. ICMA Press, Washington DC, p 52–54
- Anderson, J, Butler W (1999) The University of Texas at Austin campus master plan. University of Texas at Austin. <http://www.lib.utexas.edu/books/campusmasterplan/toc.html>. Accessed 15 Sep 2016
- Arbor Day Foundation (2013) Arbor Day Foundation and Toyota celebrate fifth anniversary of Tree Campus USA. <http://www.arborday.org/media/pressreleases/pressreleasetxt.cfm?id=320>. Accessed 15 Sep 2016
- Arbuthnott KD (2010) Taking the long view: Environmental sustainability and delay of gratification. Anal Soc Issue Public Policy 10:4–22
- Armstrong RP (2012) Green space in the gritty city: The planning and development of Philadelphia's park system, 1854–1929. Dissertation, Lehigh University, Bethlehem, PA
- Barrata EA (2002) The performance of history and design in Paul Cret's Rittenhouse Square. Masters Thesis, University of Pennsylvania, Philadelphia, PA
- Bassett CG (2015) The environmental benefits of trees on an urban university campus. Master of Environmental Studies, University of Pennsylvania, Philadelphia, PA
- Battaglia M et al. (2014) It's not easy going green: Obstacles to tree-planting programs in East Baltimore. Cities Environ 7(2):article 6
- Berland A (2012) Long-term urbanization effects on tree cover along an urban-rural gradient. Urb Ecosyst 15:721–738
- Birch E, Perry DC, Taylor HL (2013) Universities as anchor institutions. J Higher Educ Outreach Engagem 17:7–15
- Bishop KR (2013) 'Design with nature and culture': The landscapes of George Erwin Patton. Masters Thesis, University of Pennsylvania, Philadelphia, PA
- Boone CG, Cadenasso ML, Grove JM et al. (2010) Landscape, vegetation characteristics, and group identity in an urban and suburban watershed: Why the 60s matter. Urb Ecosyst 13:255–271
- Boyd J (1929) A history of the Pennsylvania horticultural society 1827–1927. Pennsylvania Horticultural Society, Philadelphia, PA
- Bradley SM (2009) Harlem vs. Columbia University: Black student power in the late 1960s. University of Illinois, Urbana, IL
- Brownlee DB (1989) Building the City Beautiful: The Benjamin Franklin Parkway and the Philadelphia Museum of Art. University of Pennsylvania Press, Philadelphia, PA
- Campanella TJ (2003) Republic of Shade. Yale University Press, New Haven, CT
- Campbell L (2015) Encountering the urban forest. The Nature of Cities 4 March 2015. [www.thenatureofcities.com/2015/03/04/encountering-the-urban-forest](http://www.thenatureofcities.com/2015/03/04/encountering-the-urban-forest). Accessed 9 Aug 2017
- Center for Environmental Design (CED) (1977) Landscape development plan. Graduate School of Fine Arts, University of Pennsylvania, Philadelphia, PA
- City of New York (2012) PlaNYC 2030 – About PlaNYC. <http://www.nyc.gov/html/planyc2030/html/about/about.shtml>. Accessed 28 Nov 2016
- City of Philadelphia (2009) Greenworks Philadelphia. Mayor's Office of Sustainability. <https://beta.phila.gov/documents/greenworks-progress-reports>. Accessed 24 Jan 2017
- City of Philadelphia (2011) Green city, clean waters. Philadelphia Water Department. [www.phillywatersheds.org/doc/GCCW\\_AmendedJune2011\\_LOWRES-web.pdf](http://www.phillywatersheds.org/doc/GCCW_AmendedJune2011_LOWRES-web.pdf). Accessed 10 May 2016
- City of Philadelphia (2015) Greenworks Philadelphia: 2015 progress report. <https://beta.phila.gov/documents/greenworks-progress-reports>. Accessed 24 Jan 2017
- Clark JR, Matheny NP, Cross G, Wake V (1997) A model of urban forest sustainability. J Arboric 23:17–30
- Conway TM, Shakeel T, Atallah J (2011) Community groups and urban forestry activity: Drivers of uneven canopy cover? Landsc Urb Plan 101:231–329
- Copenheaver CA, Seiler JR, Peterson JA et al. (2014) Stadium Woods: A dendroecological analysis of an old-growth forest fragment on a university campus. Dendrochronologia 32:62–70
- Cranz G (1982) Politics of park design: A history of urban parks in America. MIT Press, Cambridge, MA
- Creswell JW (2013) Qualitative inquiry and research design: Choosing among five approaches, 3rd edn. Sage, Thousand Oaks, CA
- Cret PP, Laird WP, Olmstead Brothers (1913) Report to the Board of Trustees of the University of Pennsylvania upon the future development of buildings and grounds and the conservation of surrounding territory. University of Pennsylvania, Philadelphia, PA
- Dallett JF (1977) Letter to Mrs. John T. Nightingale. 7 Jan 1977. University of Pennsylvania Archives, Philadelphia, PA
- Daniels TL (2009) A trail across time: American environmental planning from city beautiful to sustainability. J Am Plan Assoc 75:178–192
- Dickens C (1842) American Notes for General Circulation, Vol. 1. Chapman and Hall, Strand, London
- Donovan GH, Mills J (2014) Environmental justice and factors that influence participation in tree planting programs in Portland, Oregon. U.S. Arboric Urb For 40:70–77

- Ehlerz MM (2015) Neighborhood revitalization and the anchor institution: Assessing the impact of University of Pennsylvania's West Philadelphia Initiatives on University City. *Urb Aff Rev* 52:714–750
- Eisenman TS (2016) Greening cities in an urbanizing age: The human health bases in the 19th and early 21st centuries. *Change Over Time* 6:216–246
- Ellet C, Jr (1843) A map of the county of Philadelphia from actual survey made under the direction of Charles Ellet, Jr, Civil Engineer, and in Accordance with the Act of Assembly passed June 30th, 1839, Philadelphia, PA
- Elmendorf WF, Cotrone VJ, Mullen JT (2003) Trends in urban forestry practices, programs, and sustainability: Contrasting a Pennsylvania, U.S., study. *J Arboric* 29:237–248
- Fairmount Park (1913) Report of the committee on street trees to the commissioners of Fairmount Park. Fairmount Park Historic Resources Archives, Philadelphia, PA
- Fay ML (2015) Exact McNemar's test and matching confidence intervals. R package vignette. <https://cran.r-project.org/web/packages/exact2x2/vignettes/exactMcNemar.pdf>. Accessed 15 Sep 2016
- Fisher DR, Svendsen ES, Connolly J (2015) Urban environmental stewardship and civic engagement: How planting trees strengthens the roots of democracy. Routledge, New York
- Foderaro LW (2015) Bronx planting caps off a drive to add a million trees. *The New York Times* 20 October 2017. [www.nytimes.com/2015/10/21/nyregion/new-york-city-prepares-to-plant-one-millionth-tree-fulfilling-a-promise.html?\\_r=0](http://www.nytimes.com/2015/10/21/nyregion/new-york-city-prepares-to-plant-one-millionth-tree-fulfilling-a-promise.html?_r=0). Accessed 20 July 2017
- Georgia Institute of Technology (2014) Georgia Tech 2014 campus tree care plan. Campus Tree Advisory Committee. [http://s1.facilities.gatech.edu/files/2014\\_TreeCarePlan.pdf](http://s1.facilities.gatech.edu/files/2014_TreeCarePlan.pdf). Accessed 15 Sep 2016
- Gibbons KH (2014) A framework for developing and evaluating comprehensive urban forest management plans: An analysis of Washington State Plans. Masters thesis, University of Washington, Seattle, WA
- Gillespie TW, Pincetl S, Brossard S et al. (2012) A time series of urban forestry in Los Angeles. *Urb Ecosyst* 15:233–246
- Glasker W (2002) Black students in the ivory tower: African American student activism at the University of Pennsylvania, 1967–1990. University of Massachusetts Press, Amherst, MA
- Gordon C (2003) Blighting the way: Urban renewal, economic development, and the elusive definition of blight. *Fordham Urb Law J* 31:305–337
- Grove JM, Locke DH, O'Neil-Dunne JPM (2014) An ecology of prestige in New York City: Examining the relationships among population density, socio-economic status, group identity, and residential canopy cover. *Environ Manage* 54:402–419
- Guilbert J (1995) Something that loves a wall: the yale university campus, 1850–1920. *New Engl Quart* 68:257–277
- Gumprecht B (2007) The campus as a public space in the American college town. *J Hist Geogr* 33:72–103
- Hack G, Birch EL, Sedway PH, Silver MJ eds (2009) Local planning: contemporary principles and practices. ICMA Press, Washington, DC
- Haller DM (1999) Architectural archaeology: A centennial view of the museum buildings. *Exped* 41:31–47
- Hanko K (1999) UC Green spruces up U. City. *The Daily Pennsylvanian* 15 February 1999. [www.thedp.com/article/1999/02/uc\\_green\\_spruces\\_up\\_u\\_city](http://www.thedp.com/article/1999/02/uc_green_spruces_up_u_city). Accessed 9 Aug 2017
- Hardy M (2008) UC Green turns 10, still going strong. Spruce Hill Community Association. Fall 2008 Newsletter. [www.sprucehillca.org/documents/newsletters/SHCA\\_Newsletter2008Fall.pdf](http://www.sprucehillca.org/documents/newsletters/SHCA_Newsletter2008Fall.pdf). Accessed 15 Sep 2016
- Harshberger JW (1899) The botanists of Philadelphia and their work. Press of TC Davis & Son, Philadelphia, PA
- Harshberger JW (1921) The old gardens of Pennsylvania VI.—The Woodlands, former country seat of William Hamilton. *The Garden Magazine* 33:120–124
- Hauer RJ, Peterson WD (2016) Municipal tree care and management in the United States: A 2014 urban & community forestry census of tree activities. Special Publication 16-1, College of Natural Resources, University of Wisconsin – Stevens Point, Milwaukee, WI
- Heller GL (2013) Ed Bacon: Planning, politics, and the building of modern Philadelphia. University of Pennsylvania Press, Philadelphia, PA
- Heynen NC (2003) The scalar production of injustice within the urban forest. *Antipode* 35:980–998
- Hughes S (1997) The West Philadelphia story. *The Pennsylvania Gazette* 96(2). [www.upenn.edu/gazette/1197/philly.html](http://www.upenn.edu/gazette/1197/philly.html). Accessed 10 Aug 2016
- Janda J (1995) Out of the woods and into the city. *Univ Pa Alm* 42(4):7
- Johnson G (2015) Geology Garden dates back millions of years. *PennCurrent* 17 December 2015
- Jones RE, Davis KL, Bradford J (2012) The value of trees: Factors influencing homeowner support for protecting local urban trees. *Environ Behav* 45:650–676
- Katz M (1996) Rodin hopes to push boundaries of campus farther east and south. *The Daily Pennsylvanian* 21 November 1996. [www.thedp.com/article/1996/11/rodin\\_hopes\\_to\\_push\\_boundaries\\_of\\_campus\\_farther\\_east\\_and\\_south](http://www.thedp.com/article/1996/11/rodin_hopes_to_push_boundaries_of_campus_farther_east_and_south). Accessed 20 Nov 2017
- Keefer JN (2013) Politicization of space: Urban campus, urban renewal and development in the Temple and University City areas of Philadelphia from 1947 to 1972. Dissertation, SUNY, Binghamton
- Koester RJ, Elfin J, Vann J (2006) Greening of the campus: A whole-systems approach. *J Clean Prod* 14:769–779
- Lawrence HW (2006) City Trees: A historical geography from the Renaissance through the nineteenth century. University of Virginia Press, Charlottesville, VA
- Lawrence RF, McPherson EG (2013) Governing metropolitan green infrastructure in the United States. *Landsc Urban Plan* 109:67–75
- Locke DH, King KL, Svendsen ES et al. (2014) Urban environmental stewardship and changes in vegetative cover and building footprint in New York City neighborhoods (2000–2010). *J Env Sci Stud* 4:250–262
- Locke DH, Grove JM (2015) Doing the hard work where it's easiest? Examining the relationships between urban greening programs and social and ecological characteristics. *Appl Spat Anal* 9:77–96
- Locke DH, Grove JM, Galvin M et al. (2013) Applications of urban tree canopy assessment and prioritization tools: Supporting collaborative decision making to achieve urban sustainability goals. *Cities Environ* 6:article 7
- Locke DH, Roman LA, Murphy-Dunning C (2015) Why opt-in to a planting program? Long-term residents value street tree aesthetics. *Arboricu Urb For* 41:324–333
- Long T (1991) The Woodlands: A "Matchless Place." Masters thesis, University of Pennsylvania, Philadelphia, PA
- MacDonald E (2007) Wasted space/potential place: Reconsidering urban streets. *Places* 19:11–17
- MacFarlane JM (1899) The University Botanic Garden. *Botanical Society of Pennsylvania*, Philadelphia, PA
- Madsen K (1989) To make his country smile: William Hamilton's Woodlands. *Arnoldia* 49:14–24
- Mansvelt J, Berg LD (2005) Writing qualitative geographies, constructing geographical knowledges. In: Iain Hay ed *Qualitative methods in human geography*, 2nd edn. Oxford University Press, Oxford, p 248–265

- Martin NA, Chappelka AH, Somers G et al. (2013) Evaluation of sampling protocol for i-Tree Eco: A case study in predicting ecosystem services at Auburn University. *Arboric Urb For* 39:56–61
- McBride JR, Jacobs DF (1986) Presettlement forest structure as a factor in urban forest development. *Urb Ecol* 9:245–266
- McHarg I (1969) *Design with nature*. Anchor Doubleday, Garden City, NY
- McPherson EG, Luttinger N (1998) From nature to nurture: The history of Sacramento's urban forest. *J Arboric* 24:72–88
- McPherson EG, Kotow L (2013) A municipal forest report card: Results for California, USA. *Urb For Urb Green* 12:134–143
- McWilliams J (2012) Creating Canopy initiative helps Penn earn Arbor Day Foundation's Tree Campus USA designation. *Penn-News* 9 April 2012. <https://news.upenn.edu/news/creating-canopy-initiative-helps-penn-earn-arbor-day-foundation-s-tree-campus-usa-designation>. Accessed 15 Sep 2016
- Meyer JP (2013) Denver prunes back 2006 pledge to plant 1 million trees by 2025. *Denver Post* 28 April 2013. [www.denverpost.com/2013/09/08/denver-prunes-back-2006-pledge-to-plant-1-million-trees-by-2025](http://www.denverpost.com/2013/09/08/denver-prunes-back-2006-pledge-to-plant-1-million-trees-by-2025). Accessed 20 July 2017
- Miller R, Siry J (1980) The emerging suburb: West Philadelphia, 1850–1880. *Pa Hist J Mid-Atlantic Stud* 47:99–146
- National Park Service (1995) *Historic American Building Survey (HABS)*, University of Pennsylvania, Smith Walk. HABS No. PA-6179
- National Park Service (2002). *Historic American Landscape Survey (HALS)*, John Bartram Garden and House. HALS No. PA-1
- Nguyen VD, Roman LA, Locke DH et al. (2017) Branching out to residential lands: Missions and strategies of five tree distribution programs in the U.S. *Urb For Urb Green* 22:24–35
- Nitzche G (1906) *University of Pennsylvania illustrated*. John C Winston Co, Philadelphia, PA
- Nowak DJ, Greenfield EJ (2012) Tree and impervious cover change in U.S. cities. *Urb For Urb Green* 11:21–30
- O'Mara MP (2005) Building "Brainsville": The University of Pennsylvania and Philadelphia. In: O'Mara MP ed *Cities of knowledge: Cold war science and the search for the next Silicon Valley*. Princeton University Press, Princeton, NJ, p 142–181
- O'Neill, M (1994) On campus with: Dr. Judith Rodin; In an ivy league of her own. *New York Times* 20 October 1994. [www.nytimes.com/1994/10/20/garden/on-campus-with-dr-judith-rodin-in-an-ivy-league-of-her-own.html?pagewanted=all](http://www.nytimes.com/1994/10/20/garden/on-campus-with-dr-judith-rodin-in-an-ivy-league-of-her-own.html?pagewanted=all). Accessed 9 Aug 2017.
- O'Neil-Dunne J PM (2011) A report on the City of Philadelphia's existing and possible tree canopy. University of Vermont Spatial Analysis Lab. [www.fs.fed.us/nrs/utc/reports/UTC\\_Report\\_Philadelphia.pdf](http://www.fs.fed.us/nrs/utc/reports/UTC_Report_Philadelphia.pdf). Accessed 15 Sep 2016
- Paulachok GN (1991) *Geohydrology and ground-water resources of Philadelphia, Pennsylvania*. U.S. Geological Survey water-Supply paper 2346
- Pearsall H, Pierce J (2010) Urban sustainability and environmental justice: Evaluating the linkages in public planning/policy discourse. *Local Environ* 15:569–580
- Polanski N (2015) Designing streets as environmental and economic assets for active living and healthy environments. *Transp Res J* 2521:139–148
- Popp T (2007) Mr. Olin's neighborhood. *The Pennsylvania Gazette* 105(5). [www.upenn.edu/gazette/0707/feature1.html](http://www.upenn.edu/gazette/0707/feature1.html). Accessed 20 Jul 2017
- Puckett JL, Lloyd MF (2015) *Becoming Penn: The pragmatic American university*. University of Pennsylvania Press, Philadelphia, PA, 1950–2000
- R Core Team (2015) *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. [www.r-project.org](http://www.r-project.org)
- Rodin J (2007) *The university and urban revival: Out of the ivory tower and into the streets*. University of Pennsylvania Press, Philadelphia, PA
- Rogers EB (2001) *Landscape design: A cultural and architectural history*. Harry N. Abrams, New York, NY
- Roman LA (2014) How many trees are enough? Tree death and the urban canopy. *Scenario Journal* 4. <https://scenariojournal.com/article/how-many-trees-are-enough>. Accessed 20 Jul 2017
- Roman LA, Walker LA, Martineau CM et al. (2015) Stewardship matters: Case studies in establishment success. *Urb For Urb Green* 14:1174–1182
- Rosenthal LS (1963) *A history of Philadelphia's University City*. University of Pennsylvania for the West Philadelphia Corporation. <http://uchc.net/Rosenthal/rosenthaltofc.html>. Accessed 15 Sep 2016
- Russell R (2006) 'An ornament to our city': The creation and recreation of the College of Charleston's campus, 1785–1861. *SC Hist Mag* 107:124–46
- Saffron I (2015) Changing skyline: The ugly story behind Penn's bucolic urban campus. *Philly.com* 27 November 2015. [www.philly.com/philly/living/20151127\\_Changing\\_Skyline\\_The\\_ugly\\_story\\_behind\\_Penn\\_s\\_bucolic\\_urban\\_campus.html](http://www.philly.com/philly/living/20151127_Changing_Skyline_The_ugly_story_behind_Penn_s_bucolic_urban_campus.html). Accessed 20 July 2017
- Sanchez E (2013) Celebrating the greening of University City. *University of Pennsylvania. Almanac* 60:9
- Schuyler D (1986) *The new urban landscape: The redefinition of city form in nineteenth-century America*. The Johns Hopkins University Press, Baltimore, MD
- Schwarz K, Fraglas M, Boone CG et al. (2015) Trees grow on money: Urban tree canopy cover and environmental justice. *PLoS ONE* 10:e0122051
- Severino C (1995) Greenery vs. concrete and walls vs. doors: Images and metaphors affecting an urban mission. *Metrop Univ* 6:103–111
- Shaw J. 2017. Powelton neighbors: Shooting victim was loved, a 'pillar' and 'legend'. *Philly.com* 7 February 2017. [www.philly.com/philly/blogs/real-time/Winnie-Harris-65-shot-dead-Powelton.html](http://www.philly.com/philly/blogs/real-time/Winnie-Harris-65-shot-dead-Powelton.html). Accessed 9 Aug 2017
- Silvera Seamens G (2013) Mainstreaming the environmental benefits of street trees. *Urb For Urb Green* 12:2–11
- Strom E (2005) The political strategies behind university-based development: Two Philadelphia cases. In: Perry DC, Wiewel W eds *The university as urban developer: Case studies and analysis*. ME Sharpe, Cambridge, MA
- Stroud E (2015) *Nature next door: Cities and trees in the American northeast*. University of Washington Press, Seattle, WA
- Sudow W (1999) Displacement demonized?: Towards an alternate explanation for Penn's poor relationship with West Philadelphia. Senior Thesis, University of Pennsylvania, Philadelphia, PA. [www.archives.upenn.edu/histy/features/upwphil/sudow\\_thesis.pdf](http://www.archives.upenn.edu/histy/features/upwphil/sudow_thesis.pdf). Accessed 20 July 2016
- Sutton SE (2017) *When ivory towers were black: A story about race in America's cities and universities*. Fordham University Press, New York, NY
- The Pennsylvania Gazette (1948) Expansion plans revealed. *The Pennsylvania Gazette* 42(4):13–15
- The Pennsylvania Gazette (2004) The Rodin years. May/June 2004. [www.upenn.edu/gazette/0504/index.html](http://www.upenn.edu/gazette/0504/index.html). Accessed 20 July 2017
- The Philadelphia Inquirer (1910a) Mayor to sign University bill despite protests. 15 June 1910: 1
- The Philadelphia Inquirer (1910b) Harrison offers resignation as head of U. of P. 5 October 1910:1–2
- The Philadelphia Inquirer (1931) U. of P. Trustees plan refinancing economies. 10 July 1931, 29

- Thomas GE, Brownlee DB (2000) Building America's first university: An historical and architectural guide to the University of Pennsylvania. University of Pennsylvania Press, Philadelphia, PA
- Thorpe FN (1895) The University of Pennsylvania. Harper's Magazine 542:285–302
- The Trustees Committee for the Physical Development of the University of Pennsylvania (1948) Minutes of the Trustees of the University of Pennsylvania, 25 Oct 1948
- Tranik R (1986) Finding lost space: Theories of urban design. John Wiley & Sons, Hoboken, NJ
- Tree Pittsburgh (2012) Pittsburgh urban forest master plan: A road map for effective management of our urban forest. Prepared by Davey Resource Group. <https://www.treepittsburgh.org/resource/pittsburgh-urban-forest-master-plan>. Accessed 20 July 2017
- Trustees Minutes (1876) 7 November 1876. University of Pennsylvania Archives
- Trustees Minutes (1899) 2 February 1899. University of Pennsylvania Archives
- Turner PV (1984) Campus: An American planning tradition. MIT Press, Cambridge, MA
- Tuset JJ (2014) Peter Shephard: Spaces in between the architecture and the landscape. Cuadernos de Proyectos Arquitectonicos 5:150–152
- University Archives and Records Center (2016) Mapping Penn: Land acquisitions, 1870–present. University of Pennsylvania. [www.archives.upenn.edu/MP/map.php](http://www.archives.upenn.edu/MP/map.php). Accessed 15 Sep 2016
- University of Michigan (2011) Campus forest management plan. Plant Building and Grounds Services. [www.plantops.umich.edu/grounds/pdf/UM\\_Campus\\_Forest\\_Mgmt\\_Plan.pdf](http://www.plantops.umich.edu/grounds/pdf/UM_Campus_Forest_Mgmt_Plan.pdf). Accessed 15 Sep 2016
- University of Pennsylvania (1898) Transactions and proceedings of the Botanical Society of Pennsylvania, session 1897-1898, Vol. 1, No. 1
- University of Pennsylvania (2009) Climate action plan. [www.sustainability.upenn.edu/sites/default/files/pdf/PENN-2009-Climat\\_Action\\_Plan.pdf](http://www.sustainability.upenn.edu/sites/default/files/pdf/PENN-2009-Climat_Action_Plan.pdf). Accessed 15 Sep 2016
- University of Pennsylvania (2014) Climate action plan 2.0. [www.sustainability.upenn.edu/sites/default/files/pdf/Penn%20Climate%20Action%20Plan%202.pdf](http://www.sustainability.upenn.edu/sites/default/files/pdf/Penn%20Climate%20Action%20Plan%202.pdf). Accessed 15 Sep 2016
- University of Pennsylvania (2016) About the Green Campus Partnership. [www.sustainability.upenn.edu/our-history/green-campus-partnership](http://www.sustainability.upenn.edu/our-history/green-campus-partnership). Accessed 15 Sep 2016
- University of Pennsylvania FRES (2016a) Campus development and history. [www.facilities.upenn.edu/about/campus-development-and-history](http://www.facilities.upenn.edu/about/campus-development-and-history). Accessed 15 Sep 2016
- University of Pennsylvania FRES (2016b) Penn Plant Explorer. [www.facilities.upenn.edu/services/landscape/penn-plant-explorer](http://www.facilities.upenn.edu/services/landscape/penn-plant-explorer). Accessed 15 Sep 2016
- University of Pennsylvania FRES (2017) Penn West Philadelphia campus accredited as an arboretum. 6 April 2017. [www.facilities.upenn.edu/about/news/penn-west-philadelphia-campus-a-ccredited-arboretum](http://www.facilities.upenn.edu/about/news/penn-west-philadelphia-campus-a-ccredited-arboretum). Accessed 15 Aug 2017
- Waite P (2014) Reading campus landscapes. In: Temple P ed. The physical university: Contours of space and place in higher education. Routledge, London, UK
- Weightman J (2013) University City District revitalizing inner West Philadelphia. Urban Land. <http://urbanland.uli.org/planning-design/university-city-district-revitalizing-inner-west-philadelphia>. Accessed 15 Sep 2016
- Weller R, Talarowski M (2013) Transects: 100 years of landscape architecture and regional planning at the School of Design of the University of Pennsylvania. University of Pennsylvania, Philadelphia, PA
- Wheeler SM (2000) Planning for metropolitan sustainability. J Educ Res 20:133–145
- Wilkes-Barre Times (1896) The treaty tree: Address delivered by General Hastings. Wilkes-Barre Times 6:10. April 1896
- Wilson WH (1994) The City Beautiful movement: Creating the North American landscape. Johns Hopkins University Press, Baltimore, MD
- Wirt GH (1939) Joseph trimble rothrock: father of forestry in Pennsylvania. J For 37:361–363
- Wolch JR, Bryne J, Newell JP (2014) Urban green space, public health, and environmental justice: The challenge of making cities 'just green enough'. Landsc Urb Plan 125:234–244
- Wunsch AV (2004) Woodlands Cemetery: Historic American Landscapes Survey (HALS). HALS No. PA-5. National Parks Service
- Yin RK (2009) Case study research: Design and methods, 4th edn. Sage, Thousand Oaks, CA
- Young RF, McPherson EG (2013) Governing metropolitan green infrastructure in the United States. Landsc Urb Plan 109:67–75
- Zanky M (2013) A peak inside Penn's outside spaces. PennCurrent, 12 Sep 2013. <https://penncurrent.upenn.edu/2013-09-12/latest-news/peek-inside-penn%E2%80%99s-outside-spaces>. Accessed 15 Sep 2016
- Zhou W, Huang G, Pickett STA, Cadenasso ML (2011) 90 years of forest cover change in an urbanizing watershed: Spatial and temporal dynamics. Landsc Ecol 26:645–659
- Zipperer WC, Sissini SM, Pouyat RV (1997) Urban tree cover: An ecological perspective. Urb Ecosyst 1:229–246