Integrating ecological objectives in university campus strategic and spatial planning: a case study

Daniel Eli Orenstein, David Troupin, Ella Segal, Jennifer M. Holzer and Gili Hakima-Koniak

Faculty of Architecture and Town Planning, Technion – Israel Institute of Technology, Haifa, Israel

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Abstract

Purpose – The purpose of this paper is to present a case study of how ecological considerations can be integrated into campus strategic and statutory spatial planning. A process of developing ecological objectives and guidelines for inclusion in campus strategic and statutory spatial plans is presented.

Design/methodology/approach – This case study introduces a three-phase ecological assessment process developed and applied to the Technion – IIT campus. Ecological considerations are reviewed in multiple campus strategic and spatial plans (primarily in North America and Europe) and in institutional sustainability guidelines; biodiversity and ecosystem service surveys of the campus are conducted and considered with regard to planning; university administrative structures that enable the implementation of ecological planning guidelines are also assessed.

Findings – Ecological considerations (biodiversity conservation, habitat preservation and ecosystem integrity) play a relatively minor role in sustainability planning on university campuses. The concepts of connectivity and compactness are applied broadly, but generally refer to social and educational considerations. Physical planning provides an opportunity for integrating ecological priorities into the university's mission.

Research limitations/implications – Some of the insights may not be generalizable, so it is crucial to continue accumulating similar studies. It is crucial, too, to conduct follow-up research, reporting on the ecological outcomes of plan implementation.

Practical implications – Ecological stewardship is commensurate with the sustainability commitments of universities. Considering their spatial extent and diverse locations, universities can assume an important role in ecological conservation.

Originality/value – Relatively little attention has been given to ecological considerations (biodiversity, ecological integrity and ecosystem services) in campus plans and sustainability documents. This paper suggests how universities can move towards fulfilling a role as ecological stewards through strategic and spatial planning.

Keywords Strategic planning, Biodiversity, Ecosystem services, Campus planning, Ecological sustainability, Statutory planning

Paper type Case study

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Introduction

Among the preeminent roles of the university, as defined in terms of its responsibilities towards larger society, are to prepare students to be socially responsible regional (Bodorkós and Pataki, 2009) and global citizens (Harkavy, 2006), to produce knowledge for addressing global social, economic and ecological (i.e. sustainability) challenges (Wright, 2002; Alshuwaikhat and Abubakar, 2008; Finlay and Massey, 2012) and to act as socially responsible institutions (Viebahn, 2002; Alshuwaikhat and Abubakar, 2008). As teaching and research institutions, the knowledge produced within university campuses should be applied for the benefit of humankind. In the environmental realm, universities and their faculty have been at the forefront of the modern environmental movement since its inception in the 1960s (Schoenfeld, 1979). Since that time, universities have looked inward to their own campuses to reshape them as exemplary models for sustainability, particularly within the environmental realm (Schoenfeld, 1979; Wright, 2002; Alshuwaikhat and Abubakar, 2008; Finlay and Massey, 2012). Among the many sustainability criteria are the institution's commitment towards distinctly ecological priorities, which we define as biodiversity conservation, habitat protection and restoration, maintaining and enhancing the flow of ecosystem services and maintenance and enhancement of ecological integrity. Such ecological priorities are currently a relatively minor component of the environmental considerations of universities, both in position statements and in actual planning documents.

The relatively minor contribution of ecological criteria to university sustainability efforts is apparent in global sustainability frameworks, such as the Sustainability Tracking, Assessment and Rating System (STARS) program of The Association for the Advancement of Sustainability in Higher Education and the Talloires Declaration for University Sustainability, among others (Wright, 2002). The STARS program recognizes institutions' efforts towards conserving endangered species and ecologically sensitive areas and, more generally, engagement in ecologically sustainable grounds management (Association for the Advancement of Sustainability in Higher Education, 2017). But, while these ecological considerations are explicit, they constitute only two of over 60 diverse categories that encompass multiple aspects of sustainability, from educational curriculum and research, to campus and community engagement, to university operations and planning and administration (AASHE, 2017). Similarly, the Talloires Declaration for University Sustainability, signed by more than 500 university leaders, has as one of its 10 point Action Plan items, "Practice Institutional Ecology". However, the use of the term "ecology" in this context is exemplified by, for example, resource conservation, recycling, waste reduction and environmentally sound operations (Association of University Leaders for a Sustainable Future, 1990).

Within the academic literature, there are a few studies that focus specifically on ecological considerations in university design and management (see below). However, the content of most of the research on university sustainability supports the contention that ecology plays only a small role in university sustainability planning. For example, reviews of campus sustainability activities show that efforts tend towards energy conservation, water conservation, sustainable food systems, green purchasing, solid and hazardous waste management, the built environment and transportation systems (Wright, 2002; Kermath, 2007; Brinkhurst *et al.*, 2011; Finlay and Massey, 2012; White, 2014). Indeed, the word "ecology" appears in many university guidelines and statements, although it is often used interchangeably with "environmental", and thus, "ecological" activities can be taken to mean any number of activities within the sustainability rubric, including waste reduction, resource conservation and environmental education (see Wright's overview which describes such ecological statements and activities; Wright, 2002).

A few academic studies focus on efforts to encourage specifically ecological objectives on university campuses. Griffith (1994) studied open space preservation objectives on several American university campuses, which partially overlapped with ecological objectives. She emphasizes the centrality of open space conservation (including natural areas), in part because of their ability to "establish a venerable campus identity, stir alumni sentimentalism, create a strong sense of community, and curb escalating campus densities" (Griffith, 1994; p. 648). Kermath (2007) emphasized the role of landscaping as a tool for biodiversity conservation, among other objectives. Deng *et al.* (2008) provide an example of addressing ecological objectives via landscape design using the Heriot-Watt University Campus at Riccarton (Scotland) as their case study. Krasny and Delia (2015) addressed the various benefits obtained by students who worked in natural areas on the Cornell University campus, showing empirically that "sense of place" was enhanced in students through work and recreation in campus natural areas.

The role of ecological considerations (i.e. biodiversity and habitat conservation, ecological integrity) in sustainability planning documents and master plans are diverse, with varying degrees of emphasis. In general, ecological topics are subsumed into broader sustainability priorities or as a subsidiary benefit open space conservation alongside the social, cultural, educational and recreational values offered by open spaces (University of Idaho, 2000; Brook Mcllroy Planning and Urban Design, 2003; Skidmore Owings and Merrill LLP, 2008; Campus Master Planning Team, 2011; Anonymous, 2014). The University of Massachusetts, Amherst dedicated a revision of its master plan to sustainability issues, which dealt almost exclusively with energy use and greenhouse gas emissions. When biodiversity is mentioned, it is in reference to the role of vegetation in carbon sequestration and as a subsidiary benefit of runoff water management and the creation of wetlands and ponds (Pavlova-Gillham *et al.*, 2015). In other plans, ecological considerations play a more central role, with habitat restoration and biodiversity conservation highlighted as objectives unto themselves and/or central to the core mission and identity of the institution (Goody, 2000; The University of Warwick, 2007; Sasaki, 2009; Carol R Johnson Associates Inc, 2012). Universities often express their ecological objectives within the mandate of university herbariums, arboretums and botanical gardens (Brinkhurst *et al.*, 2011).

Among the examples of university plans that do place a strong emphasis on ecological considerations, Ratajczyk *et al.* (2017) emphasize biodiversity conservation as a central feature of the University of Łódź' activities vis-a-vis the surrounding city of Łódź, Poland. The University of Nottingham in the UK boasts that their university's landscaping emphasizes biodiversity, and that their ecological efforts have been recognized with multiple awards. Their university's commitment to biodiversity conservation and other ecological principles is documented in its "Grounds Management Plan", which features a section on biodiversity management, including habitat and species management, ongoing monitoring and (synergistically) exploiting these activities for potential research, commercial and marketing opportunities (O'Grady, 2011).

The current research deals exclusively with the ecological aspects of campus design. There are three reasons why universities should be particularly concerned with ecological challenges. The first, as noted above, is their stated commitment to good citizenship and local, regional and global sustainability (i.e. "think globally"). The second is the plethora of scientific knowledge produced within universities and a fitting venue for its application, making it both efficient and appropriate for university faculty to "act locally". Finally, university campuses occupy a significant amount of land in multiple ecosystem types. The sheer spatial size of campuses and their population leads some planners (Sasaki, 2009) to compare them to, and plan them as, small cities. As such, their physical planning can have a

profound impact on ecological characteristics of their region. For example, the University of Michigan has historically occupied between 8 and 10 per cent of the total land area of Ann Arbor, MI (Brinkman, 1981). Because universities are located across the globe, in the aggregate, they can positively affect ecological conservation globally in virtually every ecosystem type.

University campuses vary widely with regard to their physical locations *vis-à-vis* cities, with some being distinctly urban, for example, Seattle University and the University of Łódź (Ratajczyk *et al.*, 2017), while others are located along a gradient between the built and the non-built environment, encompassing natural and semi-natural ecosystems (Urban Strategies, 2008). Additionally, many universities possess satellite properties that serve as nature reserves, botanical gardens and biological field stations. While some universities divert their attention to ecological priorities to these satellite properties, and they are crucial for fulfilling the universities' ecological goals and responsibilities, they do not face the same planning dilemmas as the central campuses with their multiple, often competing, development goals. The present work addresses the main core campus of universities, where most of the research, education and administration takes place.

This paper documents a case study for integrating ecological considerations into an urban university campus, the Technion – Israel Institute of Technology, via the planning process. We describe a two-year process in which an ecological advisory team worked in parallel with a larger multi-disciplinary team to produce a strategic (vision) plan and a statutory physical plan for the campus. We suggest that the process of strategic and spatial planning affords a novel and productive opportunity to integrate ecological considerations into the priorities and objectives of the university. In this case study, synergies between ecological and other university goals were successfully identified and implemented, although the process also revealed challenges in prioritizing ecological considerations.

The case study: the Technion and its ecological and planning context

The Technion – Israel Institute of Technology was founded in 1924 and the Faculty of Architecture (later Architecture and Town Planning) was among its first faculties. The university campus was located in the Hadar neighborhood of Haifa, and was moved in 1954 to a 130-hectare piece of land on a steep hillside adjacent to Haifa's Neve Sha'anan neighborhood. According to aerial photographs, the land on which the Technion was built consisted primarily of heavily grazed, Mediterranean chaparral – shrubs and annual plants – that was later forested with Stone pines and Aleppo pines (*Pinus pinea* and *Pinus halepensis*, respectively), which were popular forestry trees through most of Israel's early history (Figures 1 and 2; Tal, 2013). The topography of the campus influenced the architectural designs. Three wadis (dry riverbeds that run only following winter rains) run through the campus from south to north, two of which are on the borders of the campus and one running through the center. Early plans of the campus envisioned the central wadi as a green strip and pedestrian pathway through the campus, and building was avoided in this area (Figure 3). Between 1965 and 2012, four additional campus master plans were produced. The most recent plan allowed for 50 hectares of built space (or 38 per cent of the 130 ha campus), leaving the rest as green or grey infrastructures. Today, the southern (upslope) portion of the campus consists of a planted pine grove, while a two-hectare plot in the northern area of the campus has been designated, since 1982, as an ecological garden for teaching and research established by the late landscape ecologist Zev Naveh.

In 2012, the Technion commissioned a new master plan and turned to its Building and Maintenance Division and to the Faculty of Architecture and Town Planning to complete the task. The new planning committee was headed by architects, landscape

Figure 1.
Aerial photograph of Technion campus, circa 1962

Notes: The extent of the canopy cover within the campus and the open spaces upslope (upper right) of the campus. *Figures 1-3 reprinted with the permission of the Technion Development and Maintenance Division*

architects and planners and was supplemented with a wide range of subject-area advisors, including faculty experts in transportation, ecology, environmental psychology, education and others. Technion graduate students were also integrated into the planning staff as both advisors and research assistants. The committee had three objectives: a strategic master plan for creating the vision for the Technion, a statutory, zoning land-use plan and a plan for real-time project interventions (Assif *et al.*, 2015b).

The strategic master plan is a vision statement that aims to "enhance [the campus'] unique spatial characteristics as a home base for its faculty, staff, students and visitors, and to lead the campus towards better integration in its urban and natural contexts" (Assif *et al.*, 2015b; p. 13). It requires (and received) the approval of the institution's Board of Governors. The zoning code is a statutory document that designates permitted land uses within the Technion, which requires approval by city and regional planning committees. The

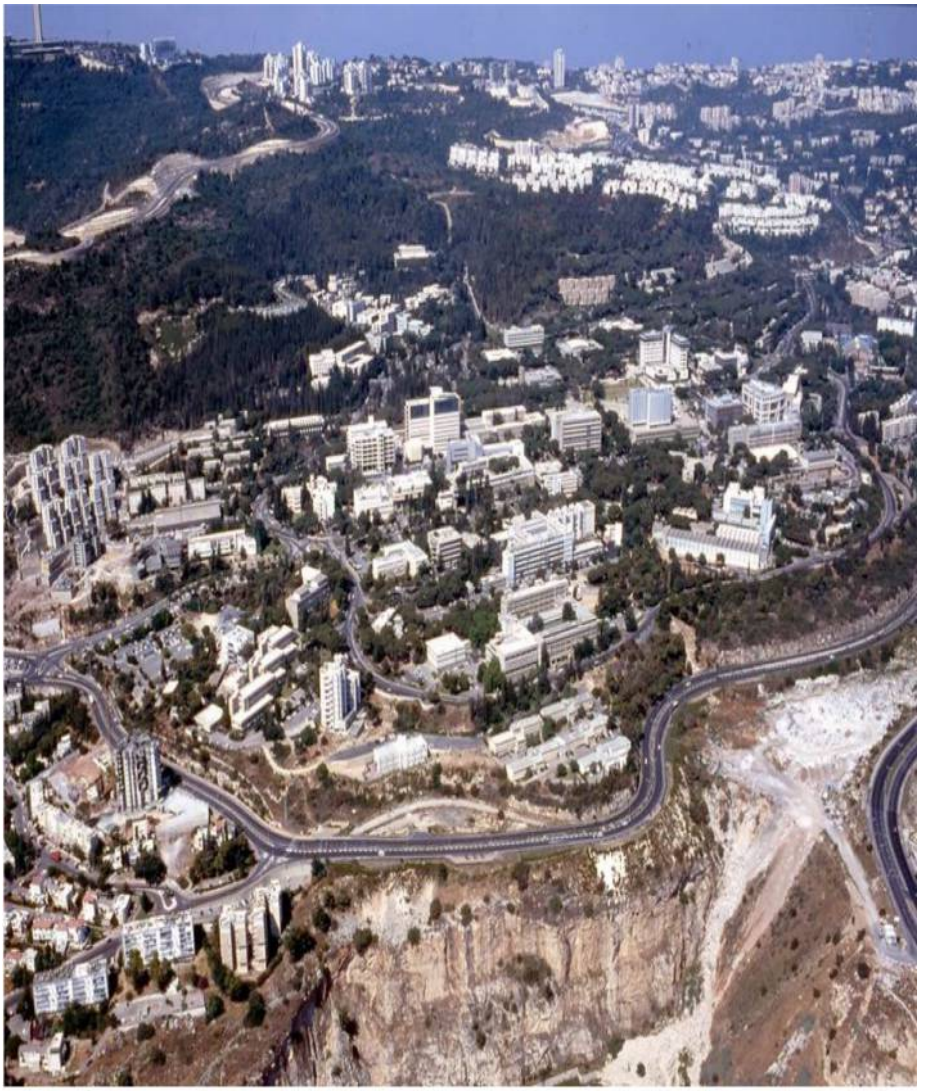


Figure 2.
Aerial photograph of Technion campus, circa 2012

Note: Urban development within and outside of the campus, as well as remaining forested open spaces

intervention and involvement plan "takes immediate action to reflect and fulfill components of the strategic plan in real time" (Assif *et al.*, 2015b; p.13).

In recognition of the planning committee's emphasis on ecological sustainability (which was, as yet, only vaguely defined), the committee provided support and resources for a multi-phase ecological assessment of the campus to receive ecologically sound recommendations.

Figure 3.
The Technion – IIT campus development plan ("Klein plan") of the 1950s, emphasizing the central green corridors designated as open space connecting the built campus

Methodology: case study of a strategic and spatial planning activity

By focusing on the ecological planning of the Technion campus, this research adopts a case study approach by looking in depth at a particular activity (Creswell, 2003), namely, the integration of ecological priorities in a university campus planning process and providing an account of the results and the lessons learned. A case study provides "concrete, context-dependent knowledge" (Flyvbjerg, 2006), that, while specific to the study, can offer broader lessons for other cases. In our example, we recount the process in which ecological objectives and guidelines were determined and integrated into the university's strategic and spatial plans and elaborate upon the tools that were suggested to facilitate their implementation. The experience is instructive and valuable because:

- The opportunity for ecologists to participate as equal members of a broad planning effort seems relatively rare in university campus planning.
- The ecological objectives and tools can be broadly applied across university campuses globally (with some modification for local specificities).
- From among the rare examples of university plans that integrated ecological considerations, the researchers identified common themes that should be considered across all university campuses.

The authors were charged by the university planning committee with the responsibility to define ecological objectives for the university and suggest guidelines and tools for meeting those objectives. To fulfill this responsibility, we created a three-step methodological protocol described below to:

(1) collect insights from other cases around the world with regard to ecological infrastructure and planning;

(2) assess the ecological resources of the campus via biodiversity surveys and stakeholder interviews; and

(3) provide concrete recommendations for the statutory outline plan, the strategic master plan and for immediate planning interventions.

We emphasize that the protocol was developed with the objective of generating a sufficient knowledge-base for informing the planning process. While accepted scientific methodologies were employed, we had neither the time nor funding to fulfill all of the rigorous prerequisites of academic research. We suggest that these limitations are entirely realistic in both the planning and the policy arenas. In fact, our protocol was partly inspired by policy analyst Eugene Bardach's recommendations for the policy realm with regard to data gathering: "The real-world settings in which policy analysis is done rarely afford the time for a research effort that would please a careful academic researcher [. . .] try to collect only those data that can be turned into "information" that, in turn, can be converted into "evidence" that has some bearing on your problem" (Bardach, 2009; p. 10).

The methodological protocol was as follows.

Phase 1. Define ecological principles and objectives in existing university campus strategic and spatial plans around the world; identify planning tools employed for realizing ecological objectives; identify administrative structures necessary for supporting ecological planning implementation

To address the questions defined for the first phase of the project, the ecological assessment team conducted a review of ecological planning on university campuses (grey literature review of publically available university spatial and strategic plans) and defined an "ecological campus" concept based on ecological principles and precedents from these universities. We further inventoried the planning tools described in these documents that were used to implement the ecological objectives defined by university planners. Next, to define what administrative structures were necessary to implement and maintain ecological objectives and how administrators integrated sustainability objectives into campus planning and management, we interviewed sustainability officers from seven US universities recognized by various sources as leaders in campus sustainability[1].

Our initial search of the academic literature for campus planning and ecological principles yielded very few research articles, and most of these used "ecology" in terms of energy and water conservation and waste flow or with reference to the university's "ecological footprint". On the other hand, there was abundant information in the grey literature that emphasizes the importance of ecological conservation and provides guidelines for campus planning and management. Our starting point was several reviews and rankings of universities published in online news websites[2]. We expanded upon the information obtained from these sources through an internet search for several relevant keyword combinations (Advanced Google Search: campus* + ecolog* + plan* + university*) specifically collecting university campus physical planning documents (excluding a vast majority of the hits that consisted of discussion groups, blog posts, press releases, news reports, course syllabi, etc). The master plans of some universities were readily available and used in this review, while other institutions had websites presenting the major components and priorities of their campus plans. We surveyed 19 planning documents and 6 planning sites from 23 universities in four countries (Table I). While not a

Table I. University plans assessed in this study (via primary documents or academic literature)

University	Country	Document	Year
Ben Gurion University of the Negev	Israel	Green Campus website (in.bgu.ac.il/green/Pages/default.aspx)	Accessed 2018
Carnegie Mellon University	USA	Campus Green Design website (www.cmu.edu/environment/campus-green-design/index.html)	Accessed 2018
Chatham University	USA	Eden Hall Campus website (www.edenhall.chatham.edu)	Accessed 2018
Cornell University	USA	The 2008 Cornell Master Plan for the Ithaca Campus	2008
Indiana University – Bloomington	USA	Campus Master Plan	2010
Oberlin College	USA	Sustainability website (www.oberlin.edu/environmental-sustainability)	Accessed 2018
Purdue University	USA	West Lafayette Master Plan Report	2009
Seattle University	USA	Grounds and Landscaping (www.seattleu.edu/grounds)	Accessed 2018
Stanford University	USA	Habitat Conservation Plan Overview	2013
St. Lawrence College	USA	Strategic Plan 2014-2019 website (www.stlawrencecollege.ca/ourfuture)	Accessed 2018
University of British Columbia	Canada	Okanagan Campus Plan	2015
University of Idaho	USA	Long-Range Campus Development Plan	2000
University of Kansas	USA	2014-2024 Campus Master Plan	2012
University of Massachusetts – Amherst	USA	Campus Master Plan	2012
		Campus Master Plan, Sustainability Chapter	2015
University of Nottingham	UK	University Park Campus Grounds Management Plan 2011-2016	2011
University of Pennsylvania	USA	Penn Connects: A Vision for the Future	2006
University of Rhode Island	USA	Kingston Campus Master Plan	2000
University of Saskatchewan	Canada	Core Area Master Plan	2003
University of Sheffield	UK	Masterplan 2014	2015
University of Tennessee – Knoxville	USA	Long Range Master Plan	2011
		Campus Landscape Vision and Site Standards	2012
University of Utah	USA	Campus Master Plan	2008
University of Warwick	UK	Main Campus Masterplan 1	2007
University of Wisconsin – Eau Claire	USA	Campus Master Plan 2010-2030	2011

comprehensive review of all available planning documents, the sample size is commensurate with other reviews, and our results were later cross-referenced and validated using earlier review article (Brinkhurst *et al.*, 2011; White, 2014).

Phase 2: Define the ecological resources and priorities of the Technion – IIT campus: Biodiversity and Ecosystem Services

Deng *et al.* (2008) describe the process of Ecological Landscape Design in the UK as a five-step process consisting of conducting a habitat survey and detailed ecological surveys, and then producing an ecological impact assessment, a landscape master plan and, finally, a long-term management plan and review. We began our process with two biodiversity surveys for the Technion campus, one for the fall season (August-September 2014) and one for the spring season (March-May 2015). During the fall survey, we assessed species richness of butterflies, birds and woody vegetation. During the spring survey, we resurveyed these three taxa (spring is when annual plants flower in Israel) and added additional surveys of terrestrial mammals and bats. For each taxon, we hired experts who each used a unique methodology for surveying their focal taxon.

For birds, butterflies and woody vegetation, we superimposed a map of the Technion with a 30 × 30 meter grid and selected 31 cells in a random stratified sample. These cells represented the range of land cover types found in the Technion – including entirely undeveloped areas (no structures or paved surfaces) and areas with partial and nearly complete artificial cover (90-100 per cent structures, paved roads etc.). In both seasons, the surveyors visited and surveyed the same sites and quantified species richness through direct observation. In addition to the random sampling, we employed an additional biodiversity surveyor to scan the entire campus in search of rare or red-listed species that might warrant special attention and possible protection.

For the terrestrial mammal survey, we used trap cameras, which were set up in 15 of the 31 grid cells where the other surveys were conducted. The 15 sites were selected to capture three land cover types – forested, open space in the middle of campus and the built environment. For bats, microphones and recording devices were deployed for several days to record echolocation calls at three locations on campus, again representing the three land cover types. The recording devices were collected and bat species were identified according to acoustic signals.

In addition to the biodiversity survey, an ecosystem service (ES) assessment of the Technion campus was conducted in 2014-2015. The assessment consisted of three steps. First, a team of researchers specializing in ecosystem services and using the ES inventory list prepared by the Israel National Ecosystem Assessment (INEA) for reference (Lotan *et al.*, 2017), conducted preliminary fieldwork to determine the presence/absence of ES in the built and forested areas of campus. Second, interviews with 27 representatives of various campus stakeholder groups (e.g. faculty, students, administrators, visitors, campus agronomist and campus architect) were conducted, aimed at defining "high priority" ES. Questions were asked regarding nature in the built area of campus (e.g. trees and vegetation in the interstitial spaces between buildings) and then about the Technion forested area. Questions included "What characteristics regarding the natural areas on campus are important to you?", "Which of the listed benefits are important to you personally?" (after the respondent was provided with a list of potential benefits), "Which of nature's benefits do you receive day-to-day on campus?", "Do you engage in outdoor activities on campus with your children or friends?" and "Are there additional benefits you receive from the natural areas on campus?" (asked after providing a scientific definition of ecosystem services). Finally, the researchers developed a matrix of high priority ES and analyzed the ES in terms of social value and connection to underlying ecosystem processes. The team then analyzed how the

provision of high priority ES would be affected by different campus development plans relative to the current state (Assif *et al.*, 2015a).

Phase 3: Development of ecological guidelines, objectives and planning tools

The third phase of the ecological assessment process consisted of developing the planning guidelines, specific ecological objectives for the Technion and planning and management strategies for inclusion in the Technion Strategic and Statutory Spatial Plans based on information developed in the previous two phases.

Results: ecological campus planning and Technion's ecological resources

Ecological planning on university campuses: Compact, Connected, Conserved

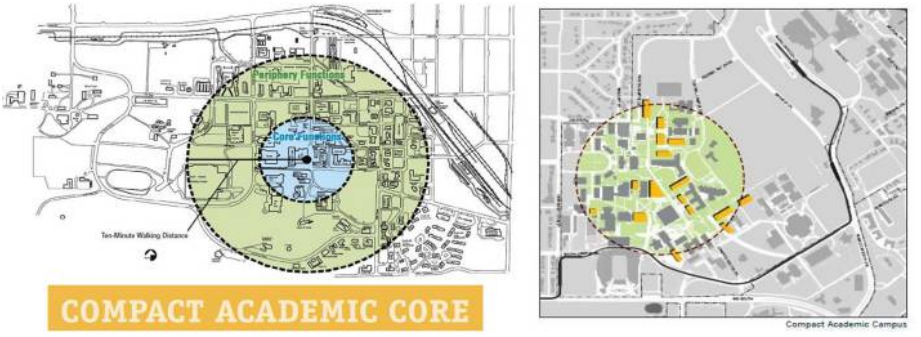
Our review of ecological planning in universities revealed three recurring principles that were common to their plans:

(1) compact development (Figure 4) – concentrating development in existing core areas; giving precedence to renovation of existing structures; and prioritizing development in areas with existing infrastructure;

(2) connectivity of open spaces and natural habitats (Figure 5) – this often includes a classification or hierarchical division of the campus into units based on multiple criteria such as land cover, hydrology, topography and land use; and

(3) conservation of high quality and key natural habitats (Figure 6) – this can include conservation of large areas as preserves or reserves, undertaking ecological reclamation and restoration projects or taking steps to improve the ecological value of habitats, also in the developed areas (e.g. vegetation, soil and water restoration, prioritizing native species in gardening and landscaping, monitoring and treating invasive species and avoiding the use of pesticides and herbicides).

While these three themes, compact, connected and conserved, are common ecological conservation principles (Groom *et al.*, 2006), we found that there were subtle differences between how the terms were being used in the university planning literature as

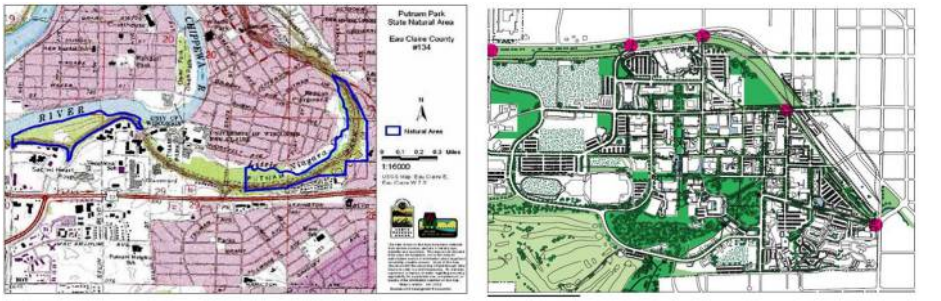


Notes: Examples in which compactness, represented by circled areas, is emphasized in campus physical plans. From the University of Idaho (left; University of Idaho, 2000) and the University of Utah (right; Skidmore Owings and Merrill LLP, 2008). *Reprinted with the permission of the planning departments of the University of Idaho and the University of Utah*

Figure 4. Compact

Notes: Examples in which connectivity, represented by shaded strips, is emphasized in campus physical plans. From Cornell University (left; Urban Strategies, 2008) and the University of Utah (right; Skidmore Owings and Merrill LLP, 2008). *Reprinted with permission from the planning departments of the Cornell University and the University of Utah*

Figure 5.
Connect



Notes: Examples in which conservation of habitat and open space, represented in outlined or shaded areas, are emphasized in campus physical plans. From The University of Wisconsin, Eau Claire (left; Campus Master Planning Team, 2011) and The University of Idaho (right; University of Idaho, 2000). *Reprinted with permission from the planning departments of the University of Wisconsin, Eau Claire and the University of Idaho*

Figure 6.
Conserve

compared to their definitions in the biological conservation literature. For instance, the three themes are used in the University of Wisconsin (UW), Eau Claire Master Plan whose vision headings are "connected and engaged", "green and open" and "compact and integrated" (Campus Master Planning Team, 2011). In this plan, as elsewhere, the three themes are consistent with ecological objectives, but ecology is not the primary focus of the themes. Rather they are associated to social, transportation and educational goals (see below and Table II).

Compact. Because of the severe impact of urban development on biodiversity (McKinney, 2002; Hansen *et al.*, 2005), compact urban development is recommended across the ecological planning literature to slow the impact of urban development and conserve open spaces for their ecological value. Compact and high-density development is recommended in many campus master plans as serving multiple economic, social and environmental goals. The

most common of these is creation of walkable and public-transit oriented campus centers, but also include efficient use of infrastructures, catalyzing social and scholarly interactions, defining a clear campus boundary and identity and preservation of open spaces elsewhere in the campus (Griffith, 1994; University of Idaho, 2000; Urban Strategies, 2008; Sasaki, 2009; Campus Master Planning Team, 2011). Most of these campus plans refer to a compact academic center, while the built environment (research parks, athletic complexes and residential areas) extend beyond this center, suggesting that ecological considerations are not the primary driver of compact development.

Connected. Connectivity between habitats is another prominent theme of the conservation ecology and planning literature (Zipperer *et al.*, 2000; Pulliam and Johnson, 2002; Ahern, 2013). Networks of open spaces are discussed in some university planning documents in terms of ecologically connectivity (Sasaki, 2009), but more often they are promoted for sense of place, integrative design with the built environment, aesthetics, providing coherence and green connectivity between the built environment and for their role as a social and recreational venues in the natural environment (University of Idaho, 2000; Brook Mcllroy Planning and Urban Design, 2003; The University of Warwick, 2007; Urban Strategies, 2008; Sasaki, 2009; Campus Master Planning Team, 2011; Carol R Johnson Associates Inc, 2012; UMass Amherst Campus Planning Division, 2012). These plans often note the ecological relevance of open space connectivity, though they give far less attention to the ecology *per se* than to the other justifications (e.g. more efficient bike and pedestrian connectivity).

Another aspect of ecological connectivity concerns the connection of a campus to prominent features of the natural environment, including rivers and other water bodies, university ecological reserves (see below) and natural landscapes. The Master Plan for the University of Wisconsin, Eau Claire, for example, aims to use campus planning to better integrate and connect the campus to The Chippewa River and Little Niagara Creek (Campus Master Planning Team, 2011).

Conserved. The third guideline, conservation of open spaces of high ecological value, is touted for multiple reasons, including, but not limited to, the goal of preserving biodiversity and important habitats. The preservation and expansion of green infrastructures is a very prominent theme within campus planning documents (University of Idaho, 2000; Sasaki, 2009; Campus Master Planning Team, 2011), although here, too, the emphasis is on human uses of green spaces and then only sometimes (and briefly) in connection to biodiversity or

Planning theme	Planning justification	Ecological justification
Compact	Maximizes energy efficiency, strengthens interaction among campus communities, conserves space for future use	Preserves maximum amount of open space for habitat; permeable ground cover for water infiltration, and carbon sequestration
Connected	Easy transportation (walking, bike riding) between various parts of campus, strengthens interaction among campus communities	Allows habitat connectivity for the movement of species, nutrients and water
Conserved	Provides areas of high cultural value; provides feelings of prestige, sentimentalism and sense of place	Provides areas of high ecological value for biodiversity conservation and ecosystem restoration

Table II.
Prominent themes drawn from university planning documents and their meanings as defined in planning and in ecological terms

habitat conservation. Prominent reasons for preserving and expanding green spaces on campuses include providing recreational spaces for the campus community, emphasizing connectivity between built spaces, strengthening the connection between the campus and local communities and enhancing the cultural relevance of the institution (Skidmore Owings and Merrill LLP, 2008; Sasaki, 2009). Water bodies, including wetlands, riparian areas and waterfronts, often receive mention for their biodiversity value and potential for restoration (Goody, 2000; The University of Warwick, 2007).

In addition to physical planning, campus master plans emphasize the importance of landscape planning and its role in achieving ecological objectives. Tree plantings are a commonplace recommendation. Some campus master plans are accompanied by a landscape vision and detailed operational instructions, such as that of University of Tennessee, Knoxville (an urban campus), which promotes the use of native plants for purposes of biodiversity enhancement and ecological health (Carol R Johnson Associates Inc, 2012). Native plants are also suggested for water conservation (e.g. at the University of Utah; Skidmore Owings and Merrill LLP, 2008).

Biodiversity and ecosystem services survey of the Technion campus

The main findings of these surveys were that the Technion Woods, a forested plot in the southern, up-slope campus, is unique in comparison to the rest of the campus, as it provides habitat for species not found elsewhere on campus, such as wild boars (*Sus scrofa*), golden jackals (*Canis aureus*), rock hyrax (*Procavia capensis*), chukar partridge (*Alectoris chukar*) and a red-listed (endangered) plant species, Myrtle (*Myrtus communis*). We concluded that the presence of these species exclusively in this area is a result of its being a part of a larger tract of natural and semi-natural areas found to the south of the Technion, on the fringes of Haifa's developed area (i.e. the rural-urban interface). Overall, the species richness found in the Technion was representative of urban areas and similar to that found in a biodiversity survey conducted in Haifa in 2012 (Wachtel *et al.*, 2012).

High priority ES, as defined in the stakeholder interviews, were primarily cultural services. Among them, "relaxation" was noted by all respondents, with respondents reporting that the green spaces on campus, where walking and sitting is "pleasant", "give a feeling of tranquility and calm" and is "good on the eyes and for the soul". The second most common ES offered by campus green spaces as noted by respondents were "existence value and biodiversity". An additional unique benefit that emerged in the interviews is the importance of nature in giving a campus a green and forested identity associated with the Mount Carmel Mediterranean ecosystem. Some respondents, particularly administrators and planners, suggested that this gave the Technion "prestige and status", as the natural elements of the campus were perceived to attract both donors and students. This finding would later play an important role in the strategic plan by connecting tree cover to the overall image of the campus. The only regulating ES that received considerable attention, and thus considerable weight when assessing the services, was providing air quality, which is particularly important considering that the campus is directly up-wind of the Haifa oil refineries and other polluting industries. No provisioning services were noted by the respondents. The research team used the ES inventory to assess how different campus development scenarios (primarily sprawled or compact development on campus in comparison to the current status) would increase or decrease the provision of these services, thereby affecting wellbeing of the campus community. Perhaps unsurprisingly, compact

development was considered to maintain or improve the provision of ES on campus relative to the current status and the sprawl scenario (Assif *et al.*, 2015a).

Administrative structure

We considered not only the ecological principles needed to protect and enhance biodiversity and ecosystem integrity on campus, but also the administrative means for implementing ecological recommendations. According to our review of campus sustainability documents and interviews with sustainability officers, we can verify that ecological priorities are generally included under the broader umbrella of "sustainability" objectives. However, while we found many campuses that emphasized carbon, water and waste policies (for example), very few explicitly noted ecological objectives.

With regard to administrative infrastructure, most campuses included in the survey have dedicated sustainability offices. To address ecological objectives, sustainability offices work closely with grounds and maintenance staff on campus, usually directed by an administrative committee. Committees are divided into subunits, each with a specific sustainability focus, for example, water, food, buildings, transportation, etc. Each of the universities surveyed had a written sustainability plan, either incorporated into a master plan or as a stand-alone document. Campuses also make significant efforts to publicize their environmental efforts and educate the campus community.

Several themes emerged from the interviews with university sustainability officers that are associated to successful implementation of sustainability policies, including:

- clearly stated sustainability goals;
- long-term commitment of the university to sustainability goals;
- a clear policy framework with clearly allocated responsibilities and oversight;
- buy-in and goodwill of the highest echelons of the university leadership;
- a reliable, consistent funding sources; and
- a charismatic and committed "sustainability" hero who initiates and/or leads the initiative. Some of these findings are reinforced in the literature (Cunningham *et al.*, 2011).

Development of an ecological vision for the Technion campus – guidelines and recommendations

The ecological advisory team concluded its work by formulating guidelines and recommendations for the planning team based on the lessons learned from other universities and the findings of the surveys conducted in the Technion. These recommendations were divided into three categories:

(1) *Implementation of the ecological planning themes*: Recommendations were in accordance with the three themes of ecological campus planning: compact development, connectivity of open spaces and conservation of ecologically valuable land. In this regard, it was recommended that the southern forest patch (The Technion Woods) and the ecological garden serve as the primary open spaces on campus and that building be avoided in these areas. Moreover, the central wadi would serve as a green belt connecting the two areas. These recommendations were adopted and reflected in the campus statutory zoning plan (Figure 7).

(2) *Management of open and interstitial spaces*: Recommendations were made that are based on intensity of land use – low intensity (the Technion Woods and the Ecological Garden), interstitial spaces and the built environment. For primarily

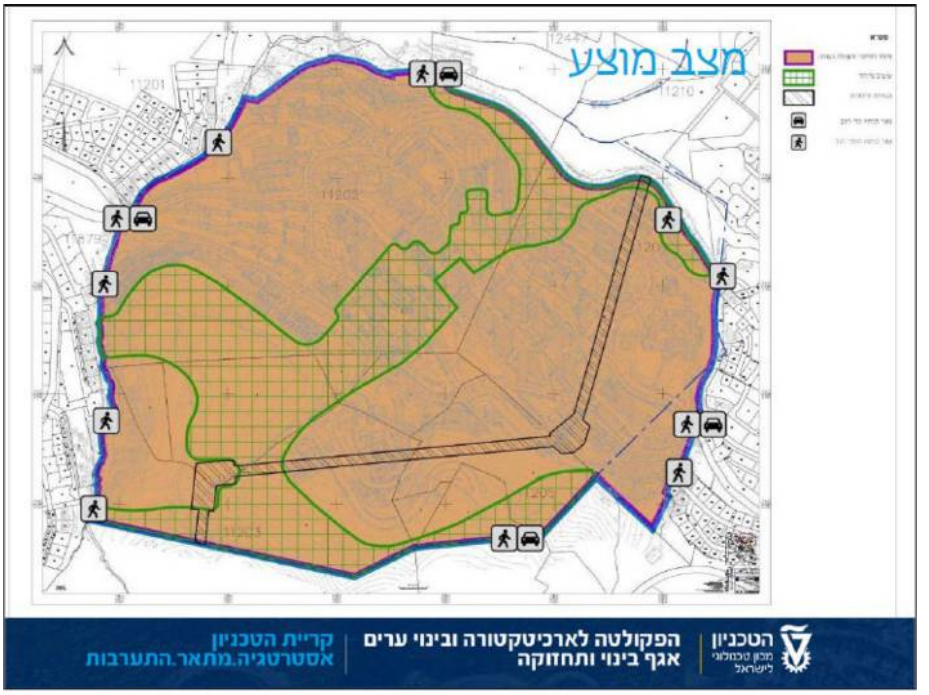


Figure 7.
The Technion Campus statutory zoning plan, approved in 2016

Notes: The Technion Woods (lower left), the central wadi and the ecological garden (upper center) are to be managed as open spaces and unique ecological management criteria have been developed for these areas and for the built environment. *Reprinted with the permission of the Technion Development and Maintenance Division*

open/natural areas, we recommended a management policy emphasizing both biodiversity potential and cultural ecosystem services. The team recommended thinning the forest in accordance with the advice of biodiversity surveyors to encourage the growth of annual plants and shrubs, thereby increasing diversity of plants and animals, as well as developing a low-impact infrastructure for human use (trails, picnic areas, educational signage) and a long-term socio-ecological research platform (Mirtl *et al.*, 2013).

Ecological gardening is emphasized for interstitial spaces between buildings and in the central campus. Landscaping, in which the use of native species is encouraged, has been emphasized as a crucial mechanism for university campuses to conserve and enhance biodiversity (Kermath, 2007). We developed two simple rules of thumb for campus gardeners which would be easily remembered and which reflect the overall findings of the biodiversity survey. First, we recommended managing gardens to increase habitat availability for birds, bees, butterflies and bats. Second, we recommended that all plant choices for campus gardens fit at least two of three criteria: Be a local species to Mount Carmel (a local protected area); be an aesthetically pleasing species; and be a species that can provide habitat for a target species from the

taxa noted above. Finally, recommendations for buildings and their immediate surroundings included the development of green roofs and walls and the placement of nesting boxes and bird feeders.

(3) *Specific projects for biodiversity and ES*. Recommendations were offered for specific projects for increasing the potential for campus biodiversity and for cultural ecosystem services. These recommendations were diverse and included the restoration of the central campus wadi, the establishment of the forest education and research site, improving access to the Ecological Garden, using a professional gardening team for the campus that also had experience in ecological gardening and coordinating ecological goals with those of transportation, education and energy. Indeed, most of the recommendations here have synergies with other campus goals including resource conservation, strengthening the physical image of campus, integrating students and staff from different faculties and more.

Ecological campus planning in the classroom

Many researchers note the importance of connecting the content of university courses with the sustainability goals of the institution, as well as preparing a cadre of young adults who are intellectually equipped to address global environmental challenges (White, 2003; Koester *et al.*, 2006; Kermath, 2007; Alshuwaikhat and Abubakar, 2008). These principles are also reflected in widely endorsed university sustainability guidelines (Association of University Leaders for a Sustainable Future, 1990; Association for the Advancement of Sustainability in Higher Education, 2017). A curriculum that emphasizes sustainability is considered a crucial component of an overall university sustainability plan, and particular courses can be designed to integrate students into the campus planning process (White, 2003). Further, the open and natural spaces of universities provide opportunities for outdoor education and in particular for ecological education. This pedagogical resource is noted in a broad sense in some campus planning documents (Urban Strategies, 2008) and more specifically in others, such as those advocating the development of outdoor classrooms for ecological education (Campus Master Planning Team, 2011). Kermath (2007) cites the use of the physical planning process as an excellent mechanism for educating landscape architects and planners about ecologically sustainable landscape planning.

Even before the beginning of the campus planning process at the Technion, the physical campus was used as a focal study object for ecology courses for landscape architecture students. Each year, graduate students in a mandatory course were required to assess the ecological challenges of the broader region (e.g. habitat degradation and loss, invasive species proliferation and species extinctions) and then propose a design intervention in the university that would address their selected challenge. Students were allowed to focus at any scale they selected, from campus-wide to a single building or small patch of ground. They chose challenges as diverse as habitat preservation for both common and endangered species, restoration of campus streams and increasing the ecological literacy of students and campus visitors. For inspiration and ideas, they were directed to the Landscape Architecture Foundation "Landscape Performance Series", which showcases projects that have received accolades for addressing ecological challenges[3]. While the students' work was intended for purely educational purposes, when the course instructor was approached to act as ecological advisor to campus planning, he was uniquely equipped with a reservoir of student-inspired ideas for implementation. Further, several students who had worked on these course projects were

recruited to work on the plans as well. As a result, several ideas directly inspired by students found their way into both the master and the statutory plans. In this way, successive generations of students acquired theoretical experience in campus planning, while learning about the potential for university campuses to serve as exemplars of ecological conservation in the urban environment. White (2003) adds a precautionary note, however, that student motivation and knowledge cannot be expected to supplant the university administrators' responsibility for overseeing campus sustainability transformations.

Discussion

In this work, we show that spatial and master planning of campuses can be an effective mechanism for advancing the ecological goals of the institution, particularly when ecological goals are synergistic with a suite of other goals, including connectivity, creating spaces for learning and social activity and creating an outdoor environment that reflects the university's cultural identity. Clearly, as a case study, our experience is context specific: We present work in a campus that straddles an urban and forested gradient, located in a Mediterranean climate with a specific national-political-planning environment. On the other hand, ecological values (i.e. the desire to conserve biodiversity and assure ecological integrity such that benefits derived from ecosystem services are assured; Müller, 2005) are universal. So we suggest that the approach introduced here, and the planning tools that were adopted for ecological objectives, also have universal relevance despite local context.

Many of the ecological recommendations mentioned above were integrated into each of the three planning products at the Technion Campus (the strategic master plan, the statutory plan and active intervention). The presence of multiple ecological concerns and objectives in the master plan document suggests that, with some initiative, ecological objectives endorsed by the plan can become operational and obligatory. The strategic master plan has been approved by the institution's board of governors and has become a binding document to be followed by all Technion offices and units.

University campuses are often considered small cities (Alshuwaikhat and Abubakar, 2008; Finlay and Massey, 2012), although they can also be conceived as part of the larger environment in which they are nested, whether it be urban, agricultural or natural (undeveloped) or some combination thereof. Reconciling and taking advantage of the Technion as a heterogeneous environment was a central feature of the planning process. The most significant contributions of the ecological assessment to the outputs of the planning process were:

- the inclusion of the Technion Woods, the Ecological Garden and the central wadi into an "Ecological-Historic Corridor" in statutory zoning; and
- the emphasis on the importance of tree-canopy cover and other ecological resources in both the strategic master plan and the statutory zoning plan.

Kermath (2007) noted that the simultaneous emphasis on cultural and natural heritage on university campuses can have a synergistic impact on both social well-being and ecological conservation. The Technion campus image, as described in the master plan, is one of a city within a forest and the plan enthusiastically endorses the value of forest cover and its benefits for both academic life and the environment. Alongside this image is the fact that the campus itself is nestled in the midst of a city and hosts a large population of students, staff and visitors. Rather than emphasize the potential conflict between these two images (city and forest), the master plan adopts the "ForestCity" image as a new and unique concept tailored for the Technion campus.

The "ForestCity" accurately reflects the physical location of the campus as a city within a forest and, simultaneously, a forest within a city. Rather than emphasize the potential conflict between these two images, the master plan adopts the hybrid image and builds upon them. As described by one of the plan's primary authors, the innovation of the plan is to highlight, "the Technion campus' unique hybrid image as a "ForestCity" – a place that has the continuous, informal, peaceful and natural elements of a forest, with the structured, creative and dynamic elements of a city" (Prof Shamay Assif, personal correspondence). Key characteristics of the "ForestCity" are the continuity, integration and accessibility of green spaces throughout the campus, emphasizing their social function (including cultural ES), as well as their ecological function (for example, as habitat for desirable species and for management of ecosystem flows).

Nearly a decade ago, Alshuwaikhat and Abubakar (2008) noted that most universities, despite environmental proclamations and commitments, approached sustainability in an ad-hoc and limited way, often focusing on a limited number of environmental parameters (this point is re-emphasized by Finlay and Massey, 2012, among others). Our analysis suggests that ecological conservation receives only limited attention in most university plans and then usually in relation to other social, economic or environmental objectives. Most plans focus primarily on energy, water and waste cycles with the objectives of conserving resources and reducing waste (Finlay and Massey, 2012). These are perceived by planners and consultants as "low-hanging fruit" that are economically beneficial in addition to their environmental benefits and are, therefore, common first steps since they can be justified financially. We suggest this is positive and desirable, but it does not allow for realizing the full potential of university campuses to be positive actors in ecological conservation. Arguably, universities that address energy, water and waste flows are addressing ecological systems from an ecosystem perspective, considering their local to global scale impact with regard to greenhouse gas emissions and energy and water consumption.

Some university plans discuss landscaping in terms of hydrological flows or [generalized] habitat creation or protection. However, very few of the outline plans we reviewed here addressed species- and habitat-level ecological conservation considerations as recommended, for example, in the ecocity model (Finlay and Massey, 2012) and in our contributions to the Technion plans. The Technion master plan directs "increased emphasis on the harmonic relationship between the campus community and the unique ecology of Mount Carmel" (Assif *et al.*, 2015b; p. 86) and sets as a planning goal "preserving and nurturing the unique natural environment in which the campus is situated" (Assif *et al.*, 2015b; p. 87).

While ecological conservation is one of many considerations driving planning objectives at the Technion, ecological considerations received greater emphasis in its strategic and statutory zoning plans than is typical of the university planning documents reviewed here and certainly more than they had in past Technion planning documents. This was made possible through collaboration between planners and an ecological advisory team, through the sponsorship of biodiversity and ecosystem service assessments and through extensive discussion, coordination and integration of ecological considerations in final planning documents. The integration of students into the planning process via academic courses created a win-win situation, provided planners and ecological advisors with ideas, models and research, while providing students with hands-on experience and the gratification of seeing some of their analyses and ideas work their way into final planning documents.

Conclusions: three challenges for ecological campuses – the Technion and beyond

We conclude with three challenges for the Technion and other campuses aspiring to be socially and ecologically responsible global institutions. The first challenge is to implement the recommendations, establish systematic monitoring of outcomes and conduct periodic revisions of objectives if and when necessary. White (2014) highlights the known challenge of bridging plans with actual implementation and realizing planning objectives on the ground. Multiple authors note that even after implementation, planning is a long-term and dynamic process whose outcomes must be monitored, reviewed and revised as needed (Griffith, 1994; Deng *et al.*, 2008; White, 2014). The test of our institution's ecological plans lie in the implementation of the master plan's ecological recommendations, but also in long-term monitoring of relevant ecological variables and flexibility to revise objectives and/or implementation tools in response to ecological outcomes, changing conditions and new insights (Ahern, 2005; Kato and Ahern, 2008).

The second challenge would be for the Technion to expand beyond the ForestCity image embodied in its approved Master Plan and adopt a Biophilic City approach. This approach, "puts nature first in [campus] design, planning and management, [recognizing] the essential need for daily human contact with nature as well as the many environmental and economic values provided by nature and natural systems" (Beatley, 2011; p. 45). The research conducted for preparing the ecological recommendations clearly show that there is a nature infrastructure in the Technion that is rich in biodiversity, with the potential to increase biodiversity if the recommendations are applied, and which offers multiple benefits for the university community. These benefits can and should be enhanced in accordance with the Technion's masterplan and its commitment to ecological sustainability, with the goal of establishing "TechCity21 as a leading campus in regard to environmental, safety and health issues [. . .] minimizing negative environmental influences on the natural urban environment [and] protecting biological diversity and ecological system services it provides [. . .]" (Assif *et al.*, 2015b, p. 19).

Regarding the third challenge, with the successful implementation of the ecological objectives outlined in the planning documents and an adoption of the "Biophilic City" approach, the Technion can become an ecological planning model for the larger metropolitan area of Haifa. This final and ambitious future challenge, inspired by the work of University of Łódź ecologists (Ratajczyk *et al.*, 2017), calls for Technion planners and scholars to take a more proactive role advancing and implementing ecological planning principles in planning for the Haifa metropolitan area and beyond. In this way, the Technion (and any university following such a path) could establish itself as a regional, national and global leader in ecological sustainability and planning.

Notes

1. The seven universities were: The University of Michigan – Ann Arbor, Cornell University, Tulane University, University of California – Merced, Towson University, Arizona State University and University of Wisconsin – Madison.
2. For example https://affordableschools.net/top-25-universities-environmental-initiatives/; http://greenmetric.ui.ac.id/; http://collegestats.org/articles/2009/10/the-nations-greenest-universities-top-10-eco-friendly-colleges/; www.princetonreview.com/green-guide.aspx. Note that these lists are developed primarily on the basis of environmental indicators that are not ecological, per se, but rather environmental, such as energy use, waste treatment, transportation policies and educational programs.
3. https://landscapeperformance.org/

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About the authors

Daniel Eli Orenstein is an Associate Professor in the Faculty of Architecture and Town Planning at the Technion – Israel Institute of Technology. He is a socio-ecologist studying the interaction of humans in nature, including human perceptions of natural landscapes and cultural ecosystem service assessment. He teaches ecology, environmental science and environmental policy for planners and architects. He is currently participating in the development and construction of a pan-European ecological and socio-ecological research infrastructure with the European Long-Term Ecological Research (LTER) Network. Daniel Eli Orenstein is the corresponding author and can be contacted at: DanielO@ar.technion.ac.il

David Troupin completed his PhD in the Technion – Israel Institute of Technology on the topic of systematic conservation planning under future uncertainty in urban development and vegetation dynamics. He now serves as Lab Manager of the Animal Flight Group in the University of Haifa. His main research interests are conservation planning and spatial ecology and movement ecology.

Ella Segal is an Ecologist with a masters from the Faculty of Architecture and Town Planning at the Technion – Israel Institute of Technology. She is currently a Researcher and Consultant specializing in conservation ecology, grazing regimes and wildfire management, particularly in Mediterranean-type ecosystems.

Jennifer M. Holzer is a PhD candidate in the Socio-Ecological Research Group at the Technion – Israel Institute of Technology in Haifa, Israel. As part of a European-funded Horizon 2020 project (eLTER – Integrated European Long-Term Ecosystem and Socio-Ecological Research Infrastructure), she is conducting a comparative case study evaluation of research activities at designated "socio-ecological research platforms" in Romania, Spain and Scotland. She has a professional background in municipal climate action planning and energy efficiency project management.

Gili Hakima-Koniak has a PhD in plant ecology and a BA in agriculture economics from the Hebrew University of Jerusalem. Her main research areas are: interdisciplinary ecology, plants and grazing, landscape management and ecosystems services.