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Food-productive green infrastructure: Enabling agroecological transitions from an urban design perspective

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Abstract

From an urban and landscape perspective, it is high time to design, plan, and build complex relationships between the urban, suburban, rural spheres in order to enable metabolic loops around food and make them compatible with environmentally sound agricultural production and socially sound urban food economies. To achieve this, we contend that it will be of ecological, economic, and social advantage for cities, towns, and countryside if existing green infrastructure (GI) concepts embraced the food subject. Green infrastructure, if food productive, can enhance nature-based solutions and be the spatial enabler of agroecological processes. Selecting the spatial landscape typology of the greenway as our example, we propose a design research pathway to explore the suitability of a 'food-productive greenway'—theoretically based on the design concept of 'Continuous Productive Urban Landscape' (CPUL)—which expands the ecological capacity of traditional GI by reorienting it toward food production and urban food system activities. We discuss this new hybrid infrastructure looking at three major space-planning functions—ecology, economy, and social impact—with a focus on landscape ecology. In the form of a 10-step plan, we include recommendations for urban planners and designers of how to consider food-productive GI as key toward an urgently needed, livable postcarbon city.

1 | INTRODUCTION: CITIES AND THE DESIGN OF FOOD-PRODUCTIVE GREEN INFRASTRUCTURE

1.1 | The need for agroecological landscapes

In its *Summary for Policymakers*, the United Nation's Intergovernmental Panel on Climate Change (IPCC) highlighted that the negative impact of industrialized agriculture on climate change is paramount (IPCC, 2018). The loss of biodiversity, nutrition, and health problems as well as the depletion of natural resources are becoming increasingly serious in the nexus between rural and urban environments. Approaches from many directions are needed to tackle these problems now and in the future. Given that land will always form a key basis for food production and food system provision, a basic approach should examine spatial considerations.

Because of continued urbanization, accelerated urban development is sprawling into peri-urban agricultural land, fragmenting urban and rural and affecting biodiversity, connectivity, and productivity (Bohn & Viljoen, 2010; Ferrario, 2009). In addition, intensive industrialized agriculture around cities has led to less accessibility between city and country.

Abbreviations: CPUL, Continuous Productive Urban Landscape; GI, green infrastructure; SELGC, South-East London Green Chain

This also means that the increasing urban population has a very limited connection to the surrounding countryside, particularly in terms of daily recreational activities, and despite the acknowledged importance of access to green space for health and leisure (Haaland et al., 2010).

In response to the IPCC's report and well-documented environmental and social problems, this paper proposes that urban planners and landscape designers join forces across disciplines to find practical and desirable solutions for sustainable urban and regional food systems. Landscape and ecology must be considered as one (Forman & Godron, 1986). People and nature coexist on earth (Forman & Godron, 1986). Agriculture, ecology, and the landscape can also be made to overlap cooperatively and fruitfully in urban space (Figure 1).

Agricultural activities—particularly those close to urban centers—must be redesigned to balance agricultural needs and ecological principles and to decrease cities' reliance on long-distance food imports and pesticides. The growing number of city mayors who have signed the "Milan Urban Food Policy Pact" (Milan Urban Food Policy Pact, 2015) indicates that more sustainable food production now seems possible. It is also increasingly urgent.

Core Ideas

- It will be of ecological, economic, and social advantage if GI embraces the food subject.
- Food-productive GI can enhance nature-based solutions as spatial enabler of agroecological processes.
- We propose a design research pathway to explore the suitability of food-productive GI.
- We discuss this new hybrid infrastructure with a focus on landscape ecology.
- We recommend a 10-step plan to consider food-productive GI for a postcarbon city.

One solution could be more widespread application of agroecological principles. In agroecosystems, agricultural production follows ecological necessity and they have been credited to support the creation of socially just food systems and places (Altieri, 1999). According to Altieri (1999), "the development of agroecological technologies and systems which emphasise the conservation-regeneration of

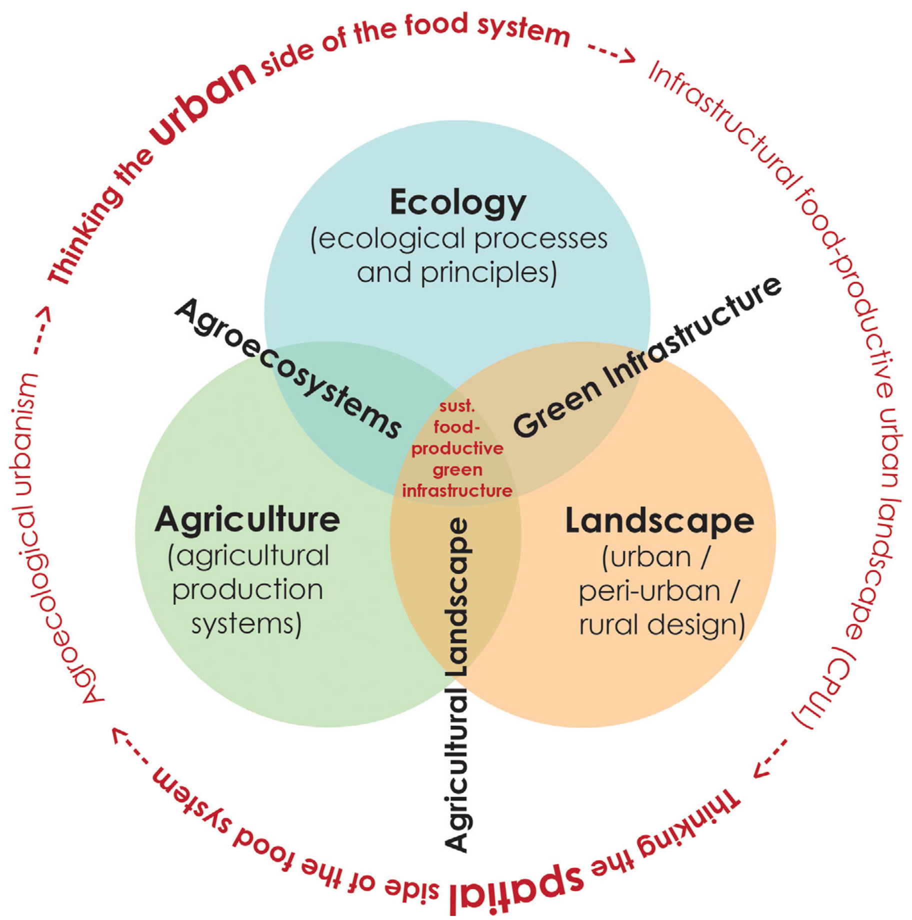

FIGURE 1 Sustainable food-productive green infrastructure at the intersection of ecology, landscape, and agriculture

biodiversity, soil, water and other resources is urgently needed to meet the growing array of socioeconomic and environmental challenges" (p. 20), which our society faces today.

The question remains: How can an agroecological farm, or a food business, achieve an identity strong enough to be recognized by local or regional planning departments and thereafter supported in the short term and protected in the long term? This paper proposes intersecting landscape, agriculture, and ecology in a new spatial typology. A sustainable food-productive GI must be defined that allows long-term integration of agroecological food provision with urban and peri-urban spatial planning.

1.2 | The lack of food in most green infrastructure concepts

It is the contention of this paper that GI concepts must include the subject of food to the ecological, economic, and social advantages of cities, towns, and countryside. Green infrastructure concepts are the basis for revaluing the role of nature within urban ecological and metabolic processes (University of the West of England, 2012). Being food productive, they can enhance nature-based solutions and be the spatial enabler for agroecological processes.

The broadly based GI concept, conceived in the USA around the turn of the century, originally related to land conservation (Firehock, 2010). Since about 2005, the concept has been developed in Europe as an EU planning policy instrument aimed at protection and improvement of ecosystem functioning for the benefit of the environment and human life. According to the first EU report on this subject, GI is defined as a "network of natural and semi-natural areas, features and green spaces' which can occur anywhere 'in urban, rural, terrestrial, freshwater, marine and coastal areas" (Naumann et al., 2011, p. 14).

Conceptually very similar, and well documented within research at the intersection of ecological economics and landscape ecology, is the multifunctional landscape that focuses on "landscapes that can provide multiple functions" and "serve multiple planning goals/objectives or values" (Kato & Ahern, 2009, p. 799). It is important to understand GI concepts in relation to multifunctionality whereby "the basic meaning of multifunctionality is that green infrastructure—or more generally, green space—provides a variety of functions, for example ecological, social, and economic ones (Pauleit et al., 2011)" (Hansen et al., 2019, p. 100). Multifunctional GI aims for "the optimisation of [such] functions of urban green space" offering "several key benefits for designing and planning sustainable cities" (Lovell & Taylor, 2013, p. 1448).

Among countries and planning authorities, the term 'green infrastructure' is used somewhat differently: Within the EU, it is defined as nature-based or man-made features, such as parks or bicycle and walking paths, and it has five main tasks: (a) biodiversity conservation, (b) promotion of human health and (societal) well-being, (c) sustainable land and water management, (d) climate change mitigation and adaptation, and (e) support for the development of a green economy (University of the West of England, 2012, pp. 1–2). Mell (2011) conducted an "extensive analysis of the green infrastructure, greenways, community forestry, urban planning and design literature produced in the UK, Europe and North America…" (p. 3) highlighting the foci of GI on (a) community forestry, (b) sustainable urban design, and (c) urban renaissance in Great Britain and on (a) climate change adaptation, (b) urban micro-climate control, and (c) biodiversity conservation in North America.

Neither the green (or multifunctional green) infrastructure concepts nor the multifunctional landscape concept mention food production or other aspects of the urban (or any) food system (Figure 2).

While food issues have slowly taken center stage with regard to community- and artist-led environmental and social initiatives over the last 40 yr (Viljoen & Bohn, 2014), until fairly recently, the main reason for the lack of food in larger-scale GI concepts is its absence as a subject for planning (Pothukuchi & Kaufman, 1999). It was only in 2007 that the American Planning Association (as the first worldwide planning organization) published its "Policy Guide on Community and Regional Food Planning" stating that "among the basic essentials for life—air, water, shelter, and food—only food has been absent over the years as a focus of serious professional planning interest. This is a puzzling omission because, as a discipline, planning marks its distinctiveness by being comprehensive in scope and attentive to the temporal dimensions and spatial interconnections among important facets of community life" (American Planning Association, 2007, p. 1) while also observing that "…over the last few years, interest in food system issues is clearly on the rise in the planning community" (American Planning Association, 2007, p. 1).

However, conceptual efforts to introduce food into the international design and planning discourse on GI have existed with the 'Continuous Productive Urban Landscape' (CPUL) concept for about 20 years. A CPUL is an urban (green) infrastructure linking food-producing sites of varying scales and operating types with other (green) open spaces through and across towns or cities, connecting those parcels of land to the citizens as well as to other food system activities and ultimately to the rural landscape (Viljoen, 2005).

To the authors' knowledge there is no earlier design concept advocating the planned integration of food production into cities at the infrastructural scale. Several contemporary concepts exist that also propose food as an important spatial dimension when envisioning cities of the future, for example, 'Sitopia' (Steel, 2008), 'Agrarian Urbanism' (De La Salle & Holland, 2010), 'Food Urbanism' (Food Urbanism, 2011),

Green infrastructure planning focus in North America	**Green infrastructure** subject focus in Europe	**Green infrastructure** planning focus in Great Britain	**Continuous Productive Urban Landscape (CPUL)** urban design focus
(i) climate change adaptation; **(ii) micro-climate control in urban areas;** **(iii) biodiversity conservation and assessments;** (iv) sustainable urban design; (v) sustainable drainage systems; (vi) smart growth; (vii) water resource management	**(i) biodiversity conservation;** **(ii) healthy lifestyles and (societal) well-being;** **(iii) sustainable land and water management;** (iv) climate change mitigation & adaptation; (v) supporting a green economy	**(i) community forestry;** **(ii) sustainable urban design;** **(iii) urban renaissance;** (iv) sustainable communities; (v) climate change adaptation; (vi) healthy lifestyles and landscapes; (vii) biodiversity conservation	**(i) urban agriculture;** **(ii) sustainable urban design;** **(iii) urban food system provision;** (iv) sustainable communities; (v) climate change mitigation; (vi) biodiversity conservation; (vii) supporting a green economy
(Mell 2011)	(UWE 2012)	(Mell 2011)	(Bohn&Viljoen 2005)

FIGURE 2 Foci of green infrastructure concepts in North America and Europe

and 'R-Urban' (Atelier d'Architecture Autogérée, 2019). It is worth mentioning too that there are historical concepts, especially Ebenezer Howard's 'garden cities', that postulate urban food system activities as part of urban development. However, to this day, there exists no large-scale, purpose-built, food-focused infrastructural productive urban landscape.

It is also apparent that the multifunctional, green landscapes occurring in urban areas have qualities very much like a CPUL. Therefore, it is conceivable that in the future, GI and multifunctional landscapes may also be adapted to the food needs of urban populations.

1.3 | A focus on landscape ecology

To determine the validity of a potential food-productive GI, a focus on landscape ecology is suggested because it encourages synergy between different fields of spatial research and practice. Mell (2011) confirmed that "although green infrastructure uses the approaches developed historically in landscape management, it applies further characteristics from landscape ecology and urban design to focus its use on current planning practice" (p. 3).

Landscape ecology is the environmental intersection of many related disciplines that focus on spatial–temporal patterns and the ecological processes of the landscape at multiple scales (Turner, 2005). It links to agroecology especially by providing an umbrella for the spatial aspects of agroecology that focus on sustainable management of agricultural landscapes. Since a CPUL is also a concept of sustainability (Viljoen, 2005), highlighted by the United Nations' University Institute of Advanced Studies as supporting biodiversity (Puppim et al., 2010), it seems sensible to determine whether a case can be made for food-productive GI, based on a landscape ecology criteria, to generate discussion and incentives that improve its adoption by local government and planning departments.

Landscape ecology can provide systemic linkages between food-productive urban landscapes and efforts to further their implementation. Because it studies the effects of spatial patterning and changes in landscape structure on the distribution, movement, and persistence of species (Turner, 1989), it can enable planners to anticipate and manage the ecological consequences of a plan (Wu, 2013). They can then provide a conceptual framework for the assessment of consequences of long-term development such as the effect of urbanization (including its food-system activities) on biodiversity. The impact of alternative planning scenarios can also be visualized and evaluated (Naveh & Lieberman, 1985).

Agroecology builds on such knowledge to consider the spatial and temporal organization of agroecosystems. It applies the study of ecological processes and ecological principles to agricultural production systems and the conjunctions created with natural social and human assets (Pretty, 2008). Between landscape ecology and agroecology exist intrinsic links that may help planners and urban designers to conceive and create GIs (Figure 3).

An important characteristic of landscape ecology is spatial heterogeneity, which encompasses biodiversity. At the same time, enhancing functional biodiversity in agroecosystems is a key ecological strategy to bring sustainability to production (Altieri, 1999). This is a significant causality between landscape ecology and agroecology, whereby the former uses biodiversity as a measure and the latter uses it as a means.

It will therefore be examined whether the spatial heterogeneity of a food-productive GI can support biodiversity because biodiversity is not only closely linked to agroecology but also to the threat of irreparable climate change.

INFRASTRUCTURAL | ECOLOGICAL

SYSTEMIC

Landscape ecology
is the intersection of many related disciplines that focus on the spatial-temporal pattern of the landscape* in order to study, maintain or improve the relationship between spatial pattern and **ecological processes** at multiple scales. An important characteristic of landscape ecology is spatial heterogeneity which encompasses **biodiversity**.

* Naveh and Lieberman 1985

Agroecology
is the study of **ecological processes** and ecological principles applied to agricultural production systems and agroecosystems. Connections are being built with natural, social and human assets*.
Biodiversity is a major indicator and assessor of agroecological quality**.

* Pretty 2008, ** Altieri 1999

SPATIAL

Green infrastructure
draws on a number of principles from **landscape ecology** promoting the maintenance of ecological resources within connected networks of green spaces*. Its utility in policy and practice lies in its ability to integrate the principles of connectivity, multifunctionality and strategic management proposed by **greenways** to support a more holistic planning approach*.

* Mell 2011

The food-productive greenway
is chosen for this design research to discuss aspects of two landscape ecology characteristics – spatial heterogeneity (focus on biodiversity) and connectivity – to extract insight on how **food-productive green infrastructure *** can (and should) become part of an urban **agroecological transition** towards liveable and sustainable cities.

* Bohn and Chu 2019

FIGURE 3 Food-productive greenway and key concepts of contemporary landscape design and environmental planning

Apart from spatial heterogeneity, connectivity is an aspect of landscape ecology most suitable for assessing food-productive GI because of its relationship to urban design and planning. A food-productive GI is a connected landscape by default, so it is sensible, as well as necessary, to assess its connectivity with a landscape ecology focus.

Spatial heterogeneity here refers to the combination of discrete and continuous variations of one or more variables in a landscape, which can be characterized as patchiness, gradients, or a mixture of both. It results from spatial interactions between several biotic and abiotic factors and various responses of organisms to these factors (Milne, 1991) as well as to the organisms themselves (Huston, 1994). Turner et al. (1989) asserted that spatial heterogeneity may significantly influence many ecosystem processes and at multiple spatial scales (Pickett & Cadenasso, 1995).

Biodiversity contributes to key ecological services, helping agroecosystems to sponsor their own soil fertility, crop protection and productivity, food security, and financial returns as well as contributing to the conservation of the world's ecosystem. In contrast, intensive industrialized agriculture with simplified biodiversity leads to a homogeneous landscape structure (Swift & Anderson, 1993) with crop monocultures that decrease local habitat diversity (Altieri & Letourneau, 1982).

Connectivity, in this context, means the degree to which a landscape facilitates or impedes the flow of energy, materials, nutrients, species, and people across the landscape. It affects the rate and pattern of flow and movement among local populations, especially spatially structured populations, and is therefore critical to their continuation particularly in fragmented landscapes (Forman, 1995; McDonnell & Pickett, 1997; Naveh, 1994; Vos & Opdam, 1993). Connectivity results from the interaction between landscape structure (e.g., the composition and configuration of the landscape mosaic) and landscape function (e.g., water flow, nutrient cycling, and maintenance of biological diversity) (Miller et al., 2006). Forman and Godron (1986), in their landscape ecology taxonomy, put forward the corridor as linear areas, or elements that differ from the surrounding matrix and may be isolated to connect patches of a similar vegetative cover (Linehan et al., 1995).

2 | METHODS: DESIGN RESEARCH

2.1 | A research pathway

The primary purpose of this paper is to promote better symmetry between GI concepts and food-productive urban landscape concepts. The intent is to generate recommendations for urban designers and planners about approaching food-productive GI as the key to a livable post-carbon city. This includes (a) describing a new food-productive GI by superimposing the differences and similarities between the greenway and CPUL concepts; (b) exploring the resulting

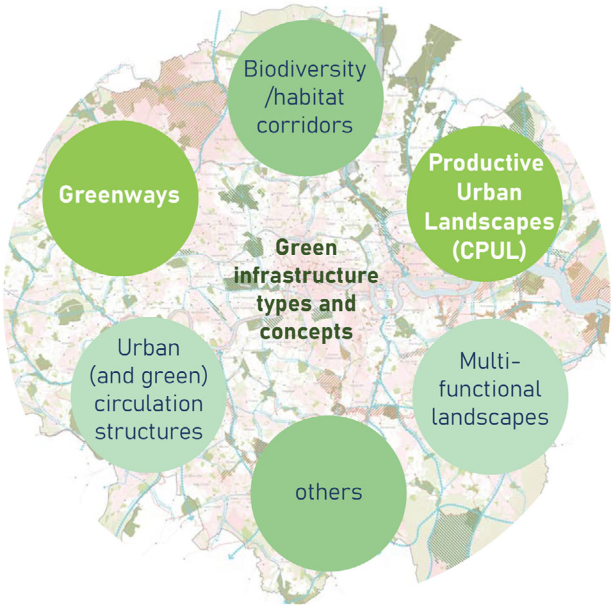

FIGURE 4 Greenway, continuous productive urban landscape, and other green infrastructure types and concepts

(imaginary) food-productive greenway through its relationships with landscape ecology and the three major space-planning functions: ecology, productivity, and social impact; and (c) using two existing case studies to sketch hypothetical before-and-after scenarios that anticipate changes to traditional greenways once they become food productive.

2.2 | The food-productive greenway as an auxiliary concept

To explore the validity of introducing food-system activities on a large scale into urban planning and design, an overlay is proposed onto an existing GI concept (not explicitly containing food production) with food. This approach allowed the authors (urban designer and landscape architect) to visualize the spatial, economic, social, and environmental characteristics of both urban landscape types and to assess their similarities and differences. It is a qualitative, design-research approach that aims to "chart the paths from research methods to research findings to design principles, to design results, and demonstrate the transformation of theory into a richly satisfying and more reliably successful practice" (Laurel, 2003).

The landscape typology of the greenway (Figure 4) has been selected from a variety of existing GI and multifunctional landscape concepts. A greenway shares many spatial characteristics with a CPUL and is therefore a tangible current (nonfood) GI concept for the purpose of exploration.

Greenways have been defined as linear corridors that improve environmental quality and provide for outdoor recreation alongside nature protection, often connecting parcels of land over long distances (Little, 1990). Greenways are "…networks of land containing linear elements that are planned, designed and managed for multiple purposes including ecological, recreational, cultural, aesthetic or other purposes compatible with the concept of sustainable land use" (Ahern, 1995, p. 134). They are regarded as actors in the protection of the ecosystem that bridge and connect rural, suburban, and urban areas from not only a spatial and temporal but also an urban metabolism perspective (Cattaneo et al., 2018). Within such a perspective, the presence of water is crucial for the understanding because many greenways developed or were developed along a defining water course, often on spaces difficult to use for other purposes. Moreover, water will be a key resource and necessity for food-productive GI, and the interdependence of food and water has been highlighted repeatedly, for example in the contexts of debates on blue-green infrastructure and nature-based solutions (Skar et al., 2020).

The greenway concept is founded on earlier use of the term by Smith Morris (1965), who described urban design in Philadelphia, PA, as well as on the practice of building what amount to greenways, even if not so called. As an example, the greenways in Chandigarh, India, may be named, planned by Albert Mayer, Mathew Novicki, and Le Corbusier in 1947, and built in the years that followed (Turner, 2015). Despite the many ecological, economic and social benefits of greenways (Tóth & Supuka, 2014), food and food system issues do not usually feature as one of these advantages.

For this design research, the greenway concept was overlaid with the CPUL design concept. The resulting (imaginary) food-productive greenway is a hybrid that superimposes the characteristics of a traditional GI with those of a food-productive GI.

It could be argued that a CPUL is itself a food-productive greenway. And, as with many concepts that strive for more environmentally conscious urban and spatial design, the conceptual boundaries between them were and are open and fluid. Since the early 2000s, Viljoen et al. (2004) have defined a CPUL as an essential urban infrastructure linking various types of food-producing and nonfood-producing spaces, whereby "linking" (in combination with the urban agriculture and food systems functions) is the unique feature of this typology. Both, the CPUL and greenway concepts stress the importance of sustainable land use and that of planning and design (Ahern, 1995; Viljoen et al., 2004).

Using the auxiliary concept of the food-productive greenway, this paper attempts to determine whether the ecological capacity of traditional GI can be expanded by reorienting it toward food production and urban food system provision. The connection of agriculture to biodiversity and local resource management could better link food-productive greenways to sustainable urban food provision in urban, as well as suburban areas. Such a hybrid infrastructure could provide the missing spatial interface between city and country, and the missing metabolic link between agricultural production and socioecological processes.

2.3 | Two case studies of existing greenways

To better visualize the spatial typology of greenways, we have chosen two different case studies reflecting current solutions to ecological landscape planning in two world cities. As "green infrastructure [...] provides a variety of functions, for example ecological, social and economic ones" (Hansen et al., 2019, p. 10"), we first examine these functions in our case studies. It is then possible to discuss how these current greenways could change to become food-productive greenways by adopting the food system activities of a CPUL as another defining feature, concentrating on food production (urban agriculture) as a major food system activity and focusing on biodiversity and connectivity.

2.3.1 | Ecology

Shanghai Houtan Park was built in 2010 on a brownfield site. Today, it is a public park where urban landscaping, ecological flood control, and wetland water purification function as an integral system. As one of the central green spaces of the Shanghai 2010 Expo, Houtan Park is a purpose-built open space designed not only as a revived ecological waterfront for exhibition but with the adaptability to be returned to that open public waterfront space. (Yu, 2015). This project is a narrow linear 14-ha band with all the characteristics of a greenway. Houtan Park can be considered a productive urban landscape providing multiple services for nature and society. After construction, the ecological credentials of the site, such as biodiversity and environmental productivity, were greatly improved.

While Shanghai Houtan Park is located within a city and contains rural, suburban, and urban aspects, the South-East London Green Chain (SELGC) is located at an urban edge that links and mediates between urban, sub-urban and rural landscapes (Figure 5). Much less visible as a *designed* open space (though much bigger in size), the SELGC was created to link the river Thames and Crystal Palace Park in London. It is part of the All London Green Grid being developed across Great Britain's capital "...to provide a strategic interlinked network of high quality green infrastructure and open spaces that connect with town centres, public transport nodes, the countryside in the urban fringe, the Thames and major employment and residential areas" (Design for London, 2015, p. 2). The SELGC is older than the Chinese example, and since 1977 it has improved the connectivity of 300 open spaces (Design for London, 2015) through individual, often small-scale measures such as gates or footpaths. The SELGC has all the characteristics of a greenway and can be considered a continuous urban landscape. After years of development, it has become a multifunctional ecosystem with improved air quality, accessibility to nature, and rich biodiversity.

2.3.2 | Social function

The site design of Shanghai Houtan Park not only evokes memories of an agricultural society, it also proposes a future ecological society. It is a reminder of the local agricultural heritage with crops planted in an ornamental way to reconnect with the site's agricultural history. Users enjoy seasonal changes with different food crops from sunflowers to rice to green clover, providing (small) economic benefits and an education in ecology and agriculture. Houtan Park is now open to the public for free and subordinated to the city administration of Shanghai. A local company was hired for its management.

Like Shanghai Houtan Park, the SELGC connects existing green parks, supporting a leisure and visitor economy for the local community that enhances economic development and quality of life. Public facilities and activities along its way are developed for residents and guests to engage with natural resources. The SELGC has established cooperative relationships with local schools and functions in several places as an outdoor classroom. Public facilities have been improved along the route, and different activities, such as sports courses and scenic walking routes, promote healthy living (Figure 6).

2.3.3 | Productivity

In Shanghai Houtan Park, food crops are planted for economic enhancement and include wheat, sunflowers, canola flowers, and cane sugar. Field testing indicates that 2,400 m^3 d^{-1} of water can be treated from lower grade V to grade II standards, which meets the daily requirements for irrigation of the landscape, road flushing, and other water needs in the park. The 585 trees in the park absorb 238 t of carbon emissions every year—a significant contribution to climate protection in the area (Turenscape, 2017).

Whilst the SELGC connects existing (urban) farms and forms a sustainable transport network, it promotes sustainable food production in only a very few of its areas by supporting existing and new allotment sites and community gardens, inviting local inhabitants to plant and harvest their own food. Such food-productive landscape elements can be found in the open space network of the Bexley area and Greenwich Park Orchard, Royal Greenwich (Design for London, 2015).

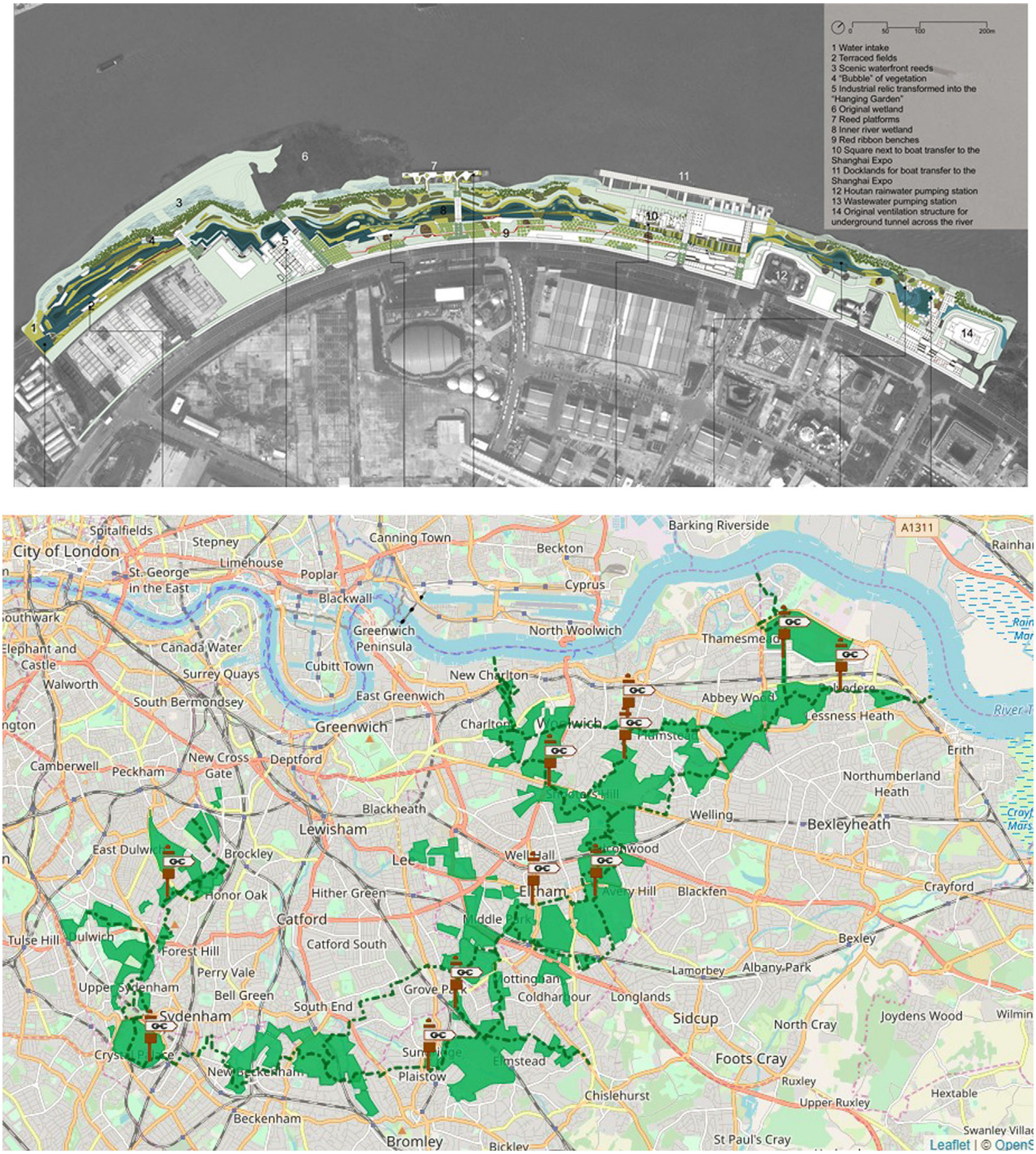

FIGURE 5 Design drawing (left, Shanghai Houtan Park) and concept drawing (right, South-East London Green Chain) within the planning processes for two existing greenways. Images: Turenscape, 2017 (left) and Transport for London, 2019 (right)

3 | FINDINGS: EXPLORING THE FOOD-PRODUCTIVE GREENWAY

3.1 | A 10-step recommendation for urban designers and planners

Despite the many arguments laid out in favor of introducing food into green infrasctructure concepts (and projects), the question of desirability remains whether to add yet another characteristic to an already generic landscape typology and further dilute the distinctions among different landscape types.

The challenges for achieving a successful food-productive GI are considerable, and careful planning, designing, and managing—as well as funding—are needed. Space-use conflicts may arise, especially within or close to expanding urban centers. While increasing biodiversity is a key goal, introducing food production to a food-productive greenway may lead

FIGURE 6 Typical spatial characteristics of Shanghai Houtan Park (left) and of the South-East London Green Chain (right). Images: Turenscape, 2017 (left) and Design for London, 2015 (right)

to the opposite, for example, to the displacement of biodiverse meadows by higher-regulated agricultural spaces. Urban and peri-urban agriculture may amplify the competition for access to local resources such as water, soil, and sunlight. There is also the question of public perception of a food-productive urban landscape that may lead to different appreciation and hence treatment of the new spaces.

However, this paper offers two predominant considerations: controlling climate change and securing diversity. Both must be addressed, and both can be addressed when the means for improving urban food systems are achieved. Key to this is the use and management of urban and peri-urban space and networks.

The European Environmental Agency (2011) states that "green infrastructure as a term does not have a single widely recognized definition. It has been adopted by the various design-, conservation- and planning-related disciplines and used to apply to slightly different concepts" (p. 30). This is of advantage as it means that integrating food can be a slightly different concept, furthering efforts to stabilize the world's climate and diversity without peripheral damage. If the case can be proved—which seems likely—there is no reason not to apply it.

The European Environmental Agency further explains: "The term [green infrastructure] is used for a network of green features that are interconnected and therefore bring added benefits and are more resilient. Another common feature is the aim to either protect or develop such networks" (European Environmental Agency, 2011, p. 30). The authors fully concur with this definition as it allows for change and adaptation within urban design and planning.

To contribute to the development of GI networks that pay particular attention to food system activities, and hence to agroecological transition, 10 steps are recommended here, which are within the urban design and planning process of future green infrastructural projects (Figure 7). They are based on the observations laid out in this paper as well as the experience of the authors as landscape architects and urban designers. The 10-step plan aims to iteratively guide the inclusion (or rejection) of food-productive spaces into GI projects and can be adapted to the different scales and characteristics of various planning proposals.

The 10-step plan (Figure 7) took inspiration from Viljoen and Bohn's (2014) CPUL City Actions Plan that offers guidance on how to implement urban agriculture projects but lacked an explicit tool for assessing potential design choices.

Step 1 acknowledges that the selection of appropriate open urban spaces is the single, one important starting point for a food-productive greenway. It is a practice-based task (marked green, Figure 7) dealing with the actual urban site or potential sequence of sites.

Steps 2 and 3 (in pink, Figure 7) echo Viljoen and Bohn's (2014) CPUL City Action "Inventory of Urban Capacity", which recommends the detailed study of a number of site characteristics in order to establish the spatial, stakeholder, managerial, and resource capacities of an urban site. Step 2 focusses on the larger-scale infrastructural functions of the selected sites and Step 3 on its individual open spaces.

Steps 4 to 6 (in blue-grey, Figure 7) describe the iterative process of design proposal and its critique, foregrounding landscape ecology as a key measure (including the evaluation of biodiversity, soil fertility, sustainable urban drainable, greenhouse gas emissions, and proximity to sources of air pollution or ground water contamination), while also addressing social and economic aspects such as visual enhancement, local identity, social equity, food justice, the creation of (green) jobs, inclusion and exclusion, and gentrification.

Steps 7 to 9 are three practice-based steps (in green, Figure 7) that include the actual implementation of a food-productive

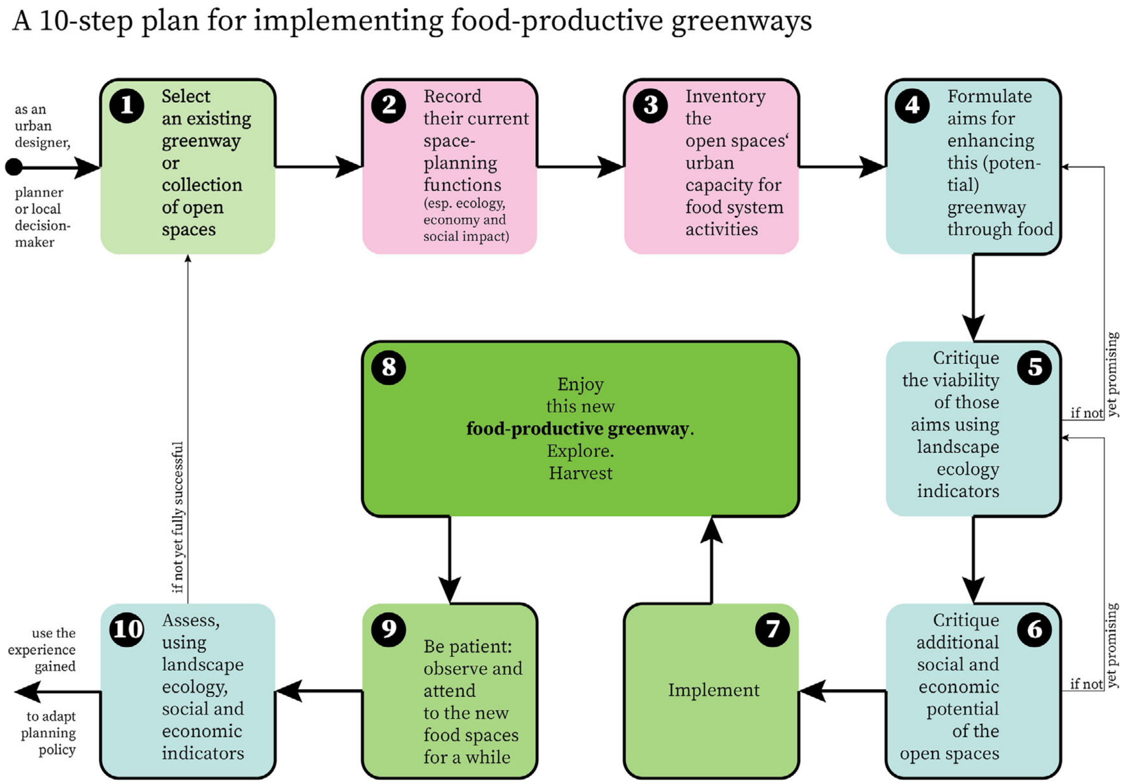

FIGURE 7 Ten-step recommendation for urban designers, planners, and local decision makers supporting development of green infrastructure with an agroecological focus

greenway. They combine convivial and food-systems activities with those of maintenance.

Step 10 (in blue-grey, Figure 7) closes the loop for continued assessment and adjustment of the food-productive greenway.

Urban agriculture and urban food systems projects have proven to work best if conducted in a codesign or participatory manner (Atelier d'Architecture Autogérée, 2019; Viljoen & Bohn, 2014). At the same time, a major challenge to the implementation of food-productive greenways can be seen in the political vulnerability of many planning offices potentially leading to the abandonment or delay of infrastructural projects, for example as a result of electoral change. Here, the authors highlight the need and opportunity for holistic cross-disciplinary approaches between many disciplines including urban planning departments, farmers, gardeners, agroecologists, geographers, local residents and politicians, landscape planners, architects, and urban designers. Within the 10-step plan, it is especially the green steps (Step 1 and Steps 7–9) that allow for codesign and coimplementation processes involving many stakeholders. Steps 2 and 3 allow for participation, especially in data collection for the inventories. Steps 4–6 and Step 10 are most likely to be conducted within urban planning offices, though this does not exclude the involvement of other stakeholders too.

3.2 | Assessing the many-faceted food-productive greenway

Green infrastructure draws on several principles from landscape ecology, promoting the maintenance of ecological resources within connected networks of green spaces (Mell, 2011). Greenways are often specifically placed to help the flow of wildlife and improve local biodiversity. According to Mell (2011): "The utility of green infrastructure in policy and practice lies in its ability to integrate the principles of connectivity, multi-functionality and strategic management proposed by greenways to support a more holistic planning approach" (p. 3).

As such, the (imaginary) food-productive greenway may offer insights when assessing the suitability of adding food system activities to green infrastructural projects (Steps 4–6 and Step 10 of the 10-step plan), both in comparison to traditional greenways and to conventional agricultural practices. It also seems appropriate to examine the food-productive greenway because it can contain urban agricultural spaces of different sizes and management, and while it may touch on small communally managed sites in some places, it can also traverse large commercially run farms. Characteristics, such as size and management, can be assessed to sufficient detail during the design processes using Steps 2 and 3 of the 10-step plan.

For final decisions, a full landscape ecology assessment will be required.

Most of the traditional greenways being planned are linear public open spaces, their main objective being to connect their individual sites with a trail path. Introducing new and different land uses for food production—small or large—into such a greenway will first lead to change in spatial heterogeneity (e.g. biodiversity) and, to a lesser extent, a change in connectivity (e.g. species flow). Ideally, the food-productive greenway will improve both of these landscape ecology characteristics and benefit from additional synergies resulting from their linkage.

For example, the adjacency and interdependence of food and water will be one of the key synergies to be explored, designed for, and celebrated. As stated earlier, greenways were often developed around existing water courses (e.g., on flood plains), which determined their form and direction. The food-productive greenway offers the opportunity to rethink open urban space focusing on metabolic processes involving the use and reuse of water for urban agricultural produce. However, if not managed appropriately, this potential positive synergy can become an environmental threat with the water needs of agricultural production depleting the water resources of greenways.

It is challenging to assess the ultimate value of a food-productive greenway because its ecological, economic, and social performance works in relation to each other depending on location. Some of its values are complex as in the case of productivity; not only is crop productivity to be calculated, but time and energy savings resulting from less food transport, and benefits related to healthy exercise, are also important factors.

3.3 | Major space-planning functions become more sustainable

3.3.1 | Economic functions

Productivity

Abundance in the food-productive greenway means both calculable and incalculable economic productivity, the latter often being related to ecology and social impact. Food-productive greenways not only enable—or improve—the agricultural output of a landscape, but they can also increase its economic value by developing green tourism and connecting specific scenic areas in the city to the suburb and the farm. How a relatively small inner-urban greenway, like food-productive Houtan Park, has increased its measurable productivity through food-system activities, is a subject for study. In a greenway that is often suburban—such as a food-productive SELGC—a network of small- and medium-sized food producers (especially with an attached direct marketing concept), would almost certainly contribute to the overall positive performance of this infrastructure, providing that ecological concerns are respected.

Transport

As connective transport routes, food-productive greenways could be as easily accessible for movement and community interaction as traditional greenways and, like them, would promote healthy transport such as cycling and walking. In terms of productivity (and ecology), it first appears that the larger a greenway, the better its transportation qualities. This would mean that both SELGC and food-productive SELGC present desirable examples for increasing urban productivity. However, it may also happen (or be designed) that a short greenway cuts across an area neglected by public transport thereby improving productivity (and ecology) in this urban area. Such a scenario is imaginable at both Houtan Park and food-productive Houtan Park. Overall, it can be said that, regarding transport, there is little difference between the two types of greenways. However, the food-productive greenway, with its closer integrated food production, may help to cut transport costs between food supplies and local outlets, thereby building a stronger local economy.

Tourism

Traditional greenways are proven to attract more tourists into an area and provide educational, scenic, recreational, and economic benefits (Linehan et al., 1995) especially for tourists seeking the experience of nature walks. Urban agricultural projects also attract visitors and are used in many European cities to promote alternative experiences especially for younger visitors (Viljoen & Bohn, 2014). It is therefore reasonable that within their network of diverse green spaces, food-productive SELGC and a food-productive Houtan Park can cater to walkers, nature-lovers, and those seeking more environmentally attuned lifestyles. Both examples could work as transport systems, promoting the diversity of local culture. Nearby cafés or urban farms selling local produce will also benefit from the increased tourism.

3.3.2 | Social functions

Food culture

The implementation of a food-productive SELGC or a food-productive Houtan Park helps recall and reinstate traditional agricultural values, practices, and knowledge, which can be shared within the urban environment. As such, they are of landscape ecological value; Naveh (1994) described landscape ecology as the study of the spatial and functional entity of natural and cultural living space. Moreover, food should be treated as part of an educational culture.

Education and recreation

Greenways can assist to meet the vital need for recreation and contact with nature (Matsuoka & Kaplan, 2008). The same is true for food-productive greenways with their potential to connect natural and agricultural values to urban and rural societies. By planting agricultural crops, cash crops, and edible flowers near human habitats, food-productive greenways can provide the opportunity for community education about agricultural values, cultures, and food systems. Ecological literacy and food literacy can be acquired together as part of a general education, such as in school-gardening classes at adjacent schools, or as recreational activities in visits to urban and connected rural farms.

Health and well-being

Greenways provide walking landscapes that contribute to the physical and mental health of the population. In addition, food-productive greenways will integrate urban, suburban, and rural populations in food-growing activities and encourage community interaction around food in an easily accessible open space. Societal interaction around food, cooking, and eating (as well as dealing with food waste) are a powerful instrument in addressing nutritional issues related to obesity and heart disease. While the inner-urban, densely programmed food-productive Houtan Park may allow for a community garden, it is possible to imagine the larger-scale, less-intensely programmed food-productive SELGC as a facilitator for various types of urban farms including those that specifically invite community participation in planting and harvesting.

Aesthetics

Future research should also acknowledge and integrate other social functions supplied by food-productive greenways such as their aesthetic quality (Teng, 2011). A variety of colors, forms, and growing types of crop plants enrich the vegetation system especially for four-season designs, which can play an important role in the dynamics of the landscape. Any fruit and vegetable production in a food-productive Houtan Park or a food-productive SELGC would follow the rules of sprouts in spring, flowers in summer, autumn fruits, and branches for winter.

3.4 | Changes in terms of connectivity

As a measure of how spatially continuous a corridor is (Forman & Godron, 1986), connectivity applies to both the traditional and the food-productive greenway; they counterbalance the fragmentation of agricultural patches, one of the most serious threats to the landscape ecosystem, especially in peri-urban landscapes. In comparison to traditional greenways, a food-productive greenway can additionally distribute food crops linearly through space.

A food-productive greenway, with intensified connections between individual food-productive spaces and between agricultural activity and nature, can function better as a socioecological system that benefits both the local and regional community through food-related practices, education, and recreation. The food-productive greenway not only connects urban surroundings and independent elements physically, but it can also enhance the interaction between nature, human society, and ecosystems. If it is well-balanced, its connectivity can contribute to metabolic circulation and circular economic development—especially around food—benefitting both urban and rural areas.

Connectivity is also determined by the presence of breaks (Forman & Godron, 1986). With a more diverse planting and cultivation pattern, an appropriately designed food-productive greenway can improve the function of the traditional greenway as a barrier or filter, preventing or impeding the movement of specific invasive organisms across the corridor (Forman & Godron, 1986).

By reducing the fragmentation of (urban) agricultural patches and strengthening their connectivity, a food-productive greenway protects the food-growing spaces in the city and suburb from outside interference. This greater connectivity not only influences the flow of water, minerals, and nutrients, it also provides a path for wildlife (and people), which, in turn, plays an important first step in reintroducing biodiversity into large-scale fields converting to agroecosystems (Perry, 2013). Nonphysical elements also flow better, for example heat, wind, sound, and energy; all lead to landscape change and landscape stability (Forman & Godron, 1986), desirable characteristics for sustainable landscapes including food-productive greenways.

3.5 | Biodiversity is enhanced in a food-productive greenway

Research shows that reintroducing a mosaic structure into conventional agricultural landscapes leads to the creation of multiple habitats for different species (Altieri, 1999); this is also one of the aims of agroecology. At the same time, ecological corridors, like greenways, influence the type of movement, rates, and patterns among habitat patches (Wojtkowski, 2010). The food-productive greenway, with its changing pattern of food growth and nonfood growing patches, can serve as an ecological corridor for the circulation of biodiversity across those patches, allowing for movement and distribution of plant species and wildlife. Additionally (or alternatively), it can also be designed as a habitat for natural enemies of invasive species or provide them with increased resources such as alternative prey or hosts (Landis, 2017) and pollen and nectar from flowering plants.

Spatial heterogeneity is believed to be a major facilitator for biological diversity (Huston, 1994; Milne, 1991; Wiens, 1976). Food-productive greenways can harbor a significant range of biodiversity within their crop and noncrop habitats. Enhancing local biodiversity is an important advantage of a food-productive greenway over conventional agricultural landscapes, the majority of which use a monoculture that makes them less able to provide for biodiversity. As long as the number of species in food-productive greenways is not reduced when human food plants are added, diversity in the new greenways will increase compared with that of traditional greenways. Biological synergies, such as in permaculture sites, can be achieved, and rotation of annual or perennial crops and multiple cropping systems will provide high levels of agricultural biodiversity (Landis et al., 2000).

Vegetation strips between integrated food-producing patches enable the food-productive greenway to inhibit soil-nutrient loss and erosion by water more effectively than either the traditional greenway or a conventional agricultural site. This patchiness of (often smaller-sized) fields also moderates various forms of natural stress better, such as in drought periods. Both characteristics enable more diverse plant and animal life. More experimentation with plant composition is also possible on smaller fields, for example, lower crops planted with taller crops help protect animals and crops from weather extremes (Wojtkowski, 2010).

Overall, a food-productive greenway seems a highly feasible option for diversifying agrolandscapes by modifying habitat connectivity and the shape and size of the traditional ecological green corridor. It can be expected to make a positive contribution to the strong influence of the traditional greenway on species' abundance and movement patterns (Turner et al., 1989).

4 | CONCLUSION: THE CASE FOR INCLUDING FOOD-PRODUCTION AND FOOD-SYSTEM ACTIVITIES IN GREEN INFRASTRUCTURAL CONCEPTS

Alternative agroecological approaches aim at breaking the monocultural practice of current methods of agricultural production. They are taking advantage of landscape ecological aspects such as integrating spatial connectivity and biodiversity into urban and landscape planning, which enhances complex interactions and synergisms and optimizes ecosystem services and processes. Considering agroecology in parallel with urbanism has the potential to depart from the traditional divide between urban and agrarian industries, where many interlinked environmental costs have long been overlooked.

To bridge the gap between environmental and food needs within an agroecological agenda, this work contends that GI must be an integral part—as well as a facilitator for—local food-system activities. Examples have shown that aligning existing GI concepts to include food-system activities can be the sustainable choice for an agroecological transition, and a food-productive GI can provide space for economic production and social benefits while addressing the key agroecological concerns of urbanization and climate change. At the same time, it has been shown that food-conscious urban design can lead to improved sustainability of urban and peri-urban agriculture when proposed management systems cooperate with significant landscape ecology indicators such as spatial heterogeneity (especially biodiversity) and connectivity.

In exploring the auxiliary concept of a food-productive greenway within a landscape ecology framework, this paper has suggested a 10-step tool that planners may use (and expand upon) when designing future food-productive GI. Sharing this work in a visually accessible format for broad audiences will facilitate discussions on the need for both innovative urban food systems and productive urban landscape planning.

Collaborative work with policy makers and funding agencies is necessary for the development of programs that support long-term, large-scale research and practice in the design of urban and peri-urban food-productive GIs. And although greenways and CPULs are currently different concepts, and the food-productive greenway is still in the imaginary stage, they can enrich and inform each other in the future.

AUTHOR CONTRIBUTIONS

Katrin Bohn: Conceptualization; Data curation; Formal analysis; Funding acquisition; Methodology; Project administration; Resources; Software; Supervision; Validation; Visualization; Writing-original draft; Writing-review & editing. Dong Chu: Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Visualization; Writing-original draft

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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