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Editors

Planning with Landscape: Green Infrastructure to Build Climate-Adapted Cities

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Introduction

The book brings together authors from different parts of the world and from across the landscape and built environments disciplines to showcase *conceptual thinking*, *best practices*, and *methodological strategies* relating to landscape planning and design with green infrastructure. The debate on green infrastructure has taken on greater importance in contemporary planning, placing the landscape in a central position not only for the building of sustainable green smart cities but also for ensuring the population's quality of life as it undergoes global changes in urban form and climate reactions. To this end, green infrastructure can help to establish renaturing strategies in cities, in which the concept of green infrastructure can be defined, structured as river basins, parks, and urban forestry, which can subsequently be more effectively aligned with grey infrastructure, if this is not replaced. Therefore, green infrastructure can be viewed as guiding the future articulations of housing, economic production, and planning for social betterment in a world that is expected to be 70% urban by 2030. However, the most crucial question addressed is: How?

Since the nineteenth century, many *theoretical* and practical experiences have attempted to integrate urban and environmental issues, revising the understanding of nature as both an object and as a way of urban thinking that explicitly looks to society and cultural appreciations of what the environment can and should do in our cities. However, we do not yet have a consensus on the methodological strategies that would guide the development of multi-scale landscape planning and design that is capable of responding to the climate emergency, the loss of heritage assets, variations in water and biodiversity quality, social inclusion, or human health and well-being. Green infrastructure has, as a consequence, emerged as a tool to support more sustainable and resilient forms of planning; however, what is the planning and design process supporting this, and what will be its impact from the global to the local scale?

A key issue that continues to require examination is how we build a planning and design process that creates technical answers to the social and ecological function of the city's demands, as stipulated in the 1996 Habitat Agenda and Millennium Goal 11.1, and more recently in paragraph 13a of the New Urban Agenda. Moreover, to successfully deliver these ambitious targets, this process needs to engage the values linked to the art and culture of place, and be capable of generating adoptive practices to fully understand the value and rights to the landscape.

The introductory chapter, “After all, what is GI?,” introduces the concept of GI, and debates its conceptual and practical foundations including its antecedents in water management, biodiversity, climate change, heritage, art, and public health, as well as the core principles that underpin its use to explain the relationship that green infrastructure planning has with nature-based solutions (NBS).

The second chapter, “Engaging Resilience: Integrating Sociocultural Dimensions into Green Infrastructure Planning,” discusses the role of citizen engagement in transforming sociocultural aspects of green infrastructure focussing on planning, designing, and delivering or more adaptable and resilient cities. Chapter 3, “Green Infrastructure in Landscape Planning and Design,” examines the contribution of green infrastructure to establishing a more holistic approach to landscape planning and design, issues often overlooked in the need to respond to alternative demands on urban land uses. This debate is elaborated upon in the fourth chapter, “An Evolving Paradigm of Green Infrastructure: Guided by Water,” which sets out how we can more effectively design for global changes in urban form as a result of climate change (and our reactions to it), based on the water systems thinking.

This fifth chapter, “Multifunctionality and Green Infrastructure Planning: Intercity Biological Corridors in Costa Rica,” presents a discussion of educational methodological strategies assessing how best to develop inter-city multifunctional biological corridors to promote self-sufficient land use via design solutions that stimulate natural and social processes of ecosystem service. The sixth chapter, “OMBÚes: Comprehensive Apprehension of Nature and Green Infrastructures,” outlines theoretical-methodological guidelines that promote a comprehensive apprehension of nature to improve the integrity of, and the physical and ecological connection between, green areas of the cities, in order to ensure urban landscapes are planned with a network of green infrastructures.

“Green Infrastructure as Urban Melody: The Integration of Landscape Principles into Green Infrastructure Planning and Design in China and the UK,” the seventh chapter, takes a more historical approach, and traces planning and design strategies exploring how the incorporation of green infrastructure is providing options for more effective social, economic, and ecological values in landscape practices in China and the UK. Chapter 8, “Greenways as Structures for Urban Change: Milan and Beijing Facing Post-Industrial Regeneration,” takes a comparable approach and examines the similarities and differences in how Milan and Beijing are approaching post-industrial landscape rehabilitation.

This is followed by Chap. 9, “Landscape, Infrastructure, and Aesthetic Dimension: Methodological Strategy for a Medium-Sized Brazilian City,” which explores the use of technical answers to ecological and social infrastructure demands, arguing that responses need to be engaged in socio-cultural values linked to the art and culture of the medium-sized Brazilian city. The authors discuss how this is possible and how planners are capable of generating practices that can be adopted by the general population, thus promoting improvements to their quality of life.

Chapter 10 views *green infrastructure as heritage* and sets out a series of methodological strategies based on ecosystem service thinking that can be used to guide the process of planning and designing urban landscapes. The use of heritage conservation as the core focus of the chapter makes strong links between planning for and the use of heritage as significant urban assets.

The eleventh chapter, "Transdisciplinary Co-design and Implementation of an Urban Ecological Green Infrastructure Landscape Performance Monitoring Plan," examines methodological strategies for urban ecological infrastructure (UEI) using water management as a core issue. The chapter argues that working within such a perspective allows cities to be more responsive in their planning or design, thus promoting an increased capacity to respond to the demands of more sustainable living.

The final chapter, "Building Other Landscapes: Renaturing Cities," brings together the key messages, themes, and options discussed within the book to illustrate how they can be used to plan and design urban landscape using green infrastructure. This is achieved using the city of Barcelona in Spain as a case study.

The book's overall theme is one of engagement with a variety of ideas drawn from across the landscape and built environment professions. By examining best practices and alternative approaches to planning and design, the book illustrates options that can be applicable in a number of geographically, politically, and environmentally diverse locations. It does not propose a single solution, either as green infrastructure or NBS, but alternatively proposes a suite of questions that planners, landscape architects, and designers need to consider to ensure cities are functional, livable, and resilient to complex socio-economic and ecological change. As urban areas continue to grow, the ability of cities to respond effectively to the growing number of climatic, health, political, and economic emergencies will be critical in developing and sustaining urban livability.

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About the Editors

Camila Gomes Sant'Anna is an architect, with specializations in landscape architecture. She is a professor in this field in the Faculty of Architecture and Urbanism at the Federal University of Goiás (UFG) in Brazil and also a cultural director at the Brazilian Landscape Association (ABAP). In recent years, she has been trying to develop a landscape planning and design process which provides an open channel for communication with students and stakeholders. She concluded her PhD at the University of Brasília (Brazil) in green infrastructure and its contribution to city landscape design. She was a visiting research fellow in the School of Environment, Education and Development at the University of Manchester, researching green infrastructure as a tool of landscape planning and design with Professor Ian Mell (SEED- UoM). While at the University of Manchester, she conducted technical visits to Italy (Politecnico di Torino) and Spain (Politecnico di Madri) and took part in multiple seminars, conferences, and workshops on climate change, landscape, green infrastructure, and social inclusion.

Ian Mell is Reader in Environmental and Landscape Planning at the University of Manchester, UK. Ian's work focuses on the development, application, and evaluation of green infrastructure policy and practice in the UK and internationally. His work examines the influence of governance, finance, and thematic understandings of landscape quality in the delivery of more sustainable places. Ian has received funding from the EU (Horizon 2020), the Newton Fund, and Defra/Natural England to develop evidence supporting the delivery of nature-based solutions and a national green infrastructure standard in the UK. He is also the author of *Global Green Infrastructure* (Routledge, 2016), *Planning Cities with Nature* (Lemes de Oliveira & Mell, 2019, Springer), and *Green Infrastructure Planning: Reintegrating Landscape in Urban Planning* (Lund Humphries, 2019).

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Chapter 1
After All, What Is GI?

Ian Mell

Abstract Green Infrastructure is discussed to mean different things in alternative geographical, ecological and socio-economic contexts. However, the growing literature focussing on what Green Infrastructure is, what it does and how it should be delivered provides a baseline set of principles that help to situate the concept in academic and practice-based debates. The promotion of connected landscapes that are multi-functional that provide access to nature at the local, city and regional scale is central to Green Infrastructure thinking. Moreover, the need to integrate socio-economic and ecological perspectives into political decision-making has been repeatedly outlined as a key variable to successful policy creation and subsequent implementation. It is also important to align current Green Infrastructure thinking with the historical antecedents of greenspace planning to examine where complementarities can be identified between the past and the present. Overall, this introductory chapter sets out the principles and history of Green Infrastructure planning illustrating the nexus of people, policy and practice that permeates through the following chapters. It also outlines the broader parameters of the debates to come and grounds them in accepted principles of existing Green Infrastructure thinking.

Since the introduction of Green Infrastructure as a concept, many things have changed in how territories and city organisations use it within the context of planning. One of the remaining unresolved issues is its relationship with the landscape. To some extent, 'landscape' was the instrument that spatial planning used to introduce ecological elements that may otherwise have been difficult to embed within planning. When additional instruments emerged, such as Green Infrastructure, which was considered to be focussed on ecological issues, greater difficulties in

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implementation began. Through this paper, we will always capitalise both – 'Green Infrastructure' and 'landscape' – in order to use them as terms of reference, both to complement each other and to juxtapose them. It is understood that the expression Green Infrastructure also covers Blue Infrastructure, i.e. aquatic ecosystems.

Keywords Principles · Connectivity · Multi-functionality · Policy · Scale · Collaboration · Practice

1.1 Introduction

As governments around the world consider their responses to COVID-19 and the Intergovernmental Panel on Climate Change (IPCC) 2021 reports the role of Green Infrastructure (GI), urban greening and Nature-Based Solutions (NBS) have become increasingly mainstream discussion points (Rastandeh & Jarchow, 2020; Mell & Whitten, 2021). Central to these conversations is the view that as a society we cannot continue to ignore the anthropogenic impacts on the world's climate. However, there remains a visible reluctance in many locations to promote systematic change in how we plan for, develop and maintain urban areas. Consequently, we can continue to identify failures in government to locate "environment" centrally in development narratives (Scott et al., 2018; Wamsler et al., 2020). The reaction to this continuing issue is critical to this compendium of essays. The following looks to the innovation embedded within GI thinking to illustrate where opportunities for built and natural environment specialists to work more collaboratively to secure a more sustainable future for everyone.

To contextualise these discussions, the following chapter will set out the arguments for the use of GI as a "go to" form of investment and management (Young, 2011; Cilliers et al., 2019). Through an outlining of the core principles associated with GI, and illustrating where their antecedents lie, the chapter introduces GI as a concept, a framework for investment and a set of elements that can be delivered. This will link the alternative ways in which GI policy and practice have been shaped by socio-economic, ecological and political factors (Mell, 2014). Moreover, it will highlight the influence of temporal, geographical, scalar and disciplinary variation in what GI is, what it should do and how it is delivered and managed (Mell & Clement, 2020; Matsler et al., 2021). These four framings are critical to understanding how GI is currently being reported in the academic and grey literature and how various stakeholders are using the terminology associated with GI to promote more attractive, functional and inclusive development (Beatley, 2012).

The discussions outlined in their introductory chapter will help situate the use of the concept in the remainder of the book. Each of the authors presented have a range of expertise in the use and understanding of GI in various geographical contexts (Nagendra & Gopal, 2010; Koc et al., 2017; du Toit et al., 2018). They expand on the discussion of the terminological diversity associated with GI, discuss its legitimacy or corruptible nature, as well as locating GI in terms of geographically or culturally specific approaches to landscape and urban planning (Garmendia et al., 2016; Wang & Banzhaf, 2018). Several themes running through the chapters provide a set of golden threads for readers. These include appreciation of the role of water in GI practice; understanding nature as a tool for investment, design and management across the world; reflections of the inclusion of cultural interpretations of heritage and art; linking GI to complex socio-economic and economic issues at a number of scales; and the ongoing promotion of ecological design in place of more traditional urban design practices (Benedict & McMahon, 2006; Mell, 2016). What is apparent throughout though is the forward-thinking nature of the examples, discussions and propositions made. The authors are utilising GI as an opportunity to address significant issues in landscape and urban planning. They are arguing for a reorientation of planning towards more ecological or nature-based thinking but are doing so within the context of understanding the constraints placed upon practitioners by economics and political indifference (Matsler et al., 2021). This chapter, and those which follow, aim to provide evidence of global best practice that can be used to influence decision-making, delivery and management at several scales.

1.2 GI Principles

The core principles of GI focus on the development of connected and multifunctional places that deliver socio-economic and ecological benefits to society and the environment (Li et al., 2005; Davies & Lafortezza, 2017). This is delivered within a holistic approach to investment that supports collaboration between stakeholders to ensure delivery of works at several scales. We also have to consider the ways in which alternative disciplines across the natural and built environment engage with the varied terminology and geography of GI. This includes its location with dominant landscape planning practices, as in Tojo and Lopez's discussion in Chap. 3, the debates presented by Sanchez et al. in Chap. 12 or Pellegrino and Ahern's analysis of designing with water in Chap. 4. These principles have been reported extensively by a range of academic and practice-based authors over a 15-year period illustrating the predominantly positive impact that the planning for, and use of, GI can have on society (Seiwert & Rößler, 2020).

1.3 Connectivity

The development of connective places is a core principle of GI. The creation of places that are linked via a network of links, hubs and nodes at a neighbourhood, city and regional scale has been key to aligning GI thinking with both landscape and urban planning (Fábos, 2004; Ahern, 2013). The use of GI to promote investment in linear features, i.e. greenways including the Atlanta BeltLine, large anchor sites including the Queen Elizabeth Olympic Park in London and smaller pocket parks and urban green spaces as seen in Singapore, can all be considered as supporting the principles of connectivity (Palardy et al., 2018). This is of specific relevance when considered in terms of equitable access, mobility and size/distance metrics of available GI (Mell & Whitten, 2021). Designing GI that offers opportunities to engage with the landscape at several scales ensures that people and ecological species can navigate inter- and intra-urban/rural boundaries effectively.

1.4 Multi-functionality

The delivery of multiple socio-economic and ecological benefits in one location is a second key principle of GI planning. The ability of planners, designers and developers to consider the ways in which GI can be planned into new developments, as well as retrofitted into existing spaces, to enhance health and well-being, ecological functionality, mitigate climate change, promote economic prosperity and meet local and strategic needs, supports the view of GI being multi-functional (Ugolini et al., 2015; Vallecillo et al., 2018). Moreover, promoting multi-functionality enables advocates to utilise the breadth of GI typologies, i.e. street trees, urban forests, waterways, parks, green walls and meanwhile green spaces, at a number of scales. However, we also need to recognise that not investments in GI need to provide all socio-economic and ecological benefits (Lovell et al., 2020). This includes reflecting on the cultural ecosystem services that GI can support, i.e. heritage, as discussed by Báthoryné, Ildikó and Valánszki in Chap. 12, and to a lesser extent by Li and Mell in Chap. 9's discussion of historical approaches to landscape architecture in China and the UK. One significant benefit of taking a multi-functional approach is the ability to offer bespoke solutions to specific issues or problems. Therefore, as long as each element of a GI network provides benefits to the wider area (and by association society), it can be considered multi-functional.

1.5 Access to Nature

The COVID-19 pandemic highlighted to many the importance of access to nature. Linked to personal and communal health and well-being, discussions of access to nature are located within a wider dialogue focussing on quality, quantity and equity (Kordshakeri & Fazeli, 2020). In many cities there is an unequal distribution of GI due to the decisions taken historically by planners and politicians. Consequently, we can identify significant variation in the types of GI, the quantity of GI and quality of those resources depending on where you live (Nesbitt et al., 2019). Within the research and practice literature, a series of benchmarks and metrics have been used to assess the ways in which GI are seen to be accessible. These include the Accessible Natural Greenspace Standard (ANGSt) in the UK and ParkScore© in the USA, which assess accessibility against specific criteria (Pauleit et al., 2003; Rigolon et al., 2018). However, these practices can underestimate the socio-economic, political or physical barriers to access created by planning. Effective GI investment therefore considers size, location, accessibility, functionality and ecological quality when examining how, where and what nature different communities can access. Thus, we should not simply consider more GI, in terms of m^2 or percentage per person (% pp) as a standalone approach to understanding access to nature, even though it may offer the most practical approach (University of Manchester et al., 2020).

1.6 Scaled Investment

The discussion of typologies, i.e. what GI is, also needs to consider at what scale investment should be located. As with considerations of connectivity and GI networks, scale draws explicitly on our understanding of systems (Hellmund & Smith, 2006). For example, water networks span geographical and administrative boundaries and need to be managed at both a catchment and a local scale. Likewise, habitats span scales from urban centres to national parks or over pan-national forests. Fabris and Li's discussion of GI development in Milan and Beijing in Chap. 10 support this view noting that considerations of connectivity and networks are critical to the creation of multi-functional landscapes. Within GI thinking an appreciation that policy, implementation and management need to be thought of at several scales is therefore implicit (Hale & Sadler, 2012; Che et al., 2014). In action this requires planners to consider what types of GI are implemented and where and how these investments link local and more strategic needs (Cambridgeshire Horizons, 2011). Moreover, as issues of climate change and health become central to discussions of GI provision, we can also examine how, and if so, whether local level action impacts upon landscape and urban functions at a different scale.

1.7 Multi-partner Approaches

To successfully deliver GI, there is a need to bring together practitioners from a range of disciplines. Planners, designers, environmental managers and hydrologists need to work with engineers, real estate specialists and health professionals to develop the most appropriate form of GI investment for a given location (Xing et al., 2017; Frantzeskaki, 2019). Sanchez et al. delve into the added value that effective collaborations can provide in their discussion of water management on the Arizona State University campus in Chap. 13. Historically though there has been a dislocation between disciplines within the natural and built environment leading to siloed practice (Mell & Clement, 2020). However, as GI has become increasingly mainstreamed, these disciplines have started to be more effectively aligned. This process has been facilitated by advocates of GI who work in the middle ground between "natural, built and "grey" infrastructure provision providing knowledge and evidence in delivery and management (Finewood, 2016). Working from a multi-partner perspective provides a greater level of expertise to development that draws on working practices, methods and a longer-term appreciation of what works. We can also argue that working collaboratively enables policies and projects to address gaps in capacity or knowledge and install within GI investment a more nuanced appreciation of how built and environmental systems can work (Zmelik et al., 2011; Lennon et al., 2016; Pauleit et al., 2019).

1.8 Integrated and Holistic Policy

If GI can be located within a multi-disciplinary dialogue, it is also possible to achieve integrated and holistic policy. This means that GI is framed as engaging with or being embedded in thinking that covers several built and natural environment issues. In addition, GI may be used to consider the linking of local, city and regional or international policy mandates, as well as examine how scaled investment can deliver multi-functional benefits (Marcucci & Jordan, 2013; Jones & Somper, 2014). However, to facilitate a forum for holistic policy formation requires a high level of engagement from multiple stakeholders and leadership from an organisation or location to integrate GI within policy (New York City Environmental Protection, 2010; Philadelphia Water Department, 2011). We can identify a growing number of cities that are placing an implicit value on GI within policy as an aid to structure investment around climate change or resilience thinking (Mayor of London, 2021). Unfortunately, this remains a long-term process and one that needs to take into account the local political, socio-economic and environment context. Evidence suggests though that such a transition towards GI led planning is becoming increasingly mainstream in parts of Europe, North America and China (Mell, 2016).

1.9 The Antecedents of GI

The discussion of GI principles can be linked directly to the legacy of environmental thinking within landscape and urban planning. An extensive literature exists showcasing the links between greenway, garden city, sustainable communities, low-impact development, landscape ecology and ecosystem services, urban and community forestry, sponge cities and NBS. Within these discussions the principles of connectivity and multi-functionality are prominent. In addition, we can identify issues of scale and the alignment of complex socio-economic and ecological knowledge as signposts between GI and other concepts. Significantly, we can see a collective understanding of the evolution of GI thinking drawing on antecedents such as greenways, to provide additional validity to the conceptualisation of GI practice (Benedict & McMahon, 2006; Walmsley, 2006). Herein lies the positives of these discussions – the promotion of a continuity of understanding between stakeholders in different geographical areas adhering to knowledge grounding in evidence (Austin, 2014; Firehock, 2015). For example, the role of stormwater management in GI development in the USA draws extensively on decades of research and practice to promote consensus between stakeholders (Hoover & Hopton, 2019; Zuniga-Teran et al., 2020). Moreover, in the UK the continuing influence of Ebenezer Howard's garden city principles within landscape and urban planning provides a level of reassurance for developers and decision-makers of the meanings attached to these concepts (Howard, 2009).

Temporally we can trace the principles integrated into GI from greenways with respect to the creation of connective landscapes allowing people to access nature and garden cities via the inclusion of scaled intervention in multi-functional environments open to all (Ahern, 1995; Town & Country Planning Association, 2012). These two approaches provide significant scaffolding for GI thinking and have allowed practitioners to draw on evidence from the mid-1800s onwards to take forward environmental enhancement work. Moreover, as environmental awareness increased following the 1960's environmental movement and the growth and landscape ecology thinking, we can identify a greater level of reflection by planners with ideas of connectivity (Pepper, 1996). Moving through the twenty-first century, we continue to see greenways and garden city principles used extensively in North American cities, Berlin and Singapore (Yuen, 1996; Lachmund, 2013). There is also a significant link between urban forestry in North America and community forestry in the UK in terms of shaping GI discourse (Konijnendijk, 2003; Conway & Urbani, 2007; England's Community Forests & Forestry Commission, 2012). In Canada and the USA, there is a wealth of evidence examining the role of urban trees and forests in delivering climatic, health and well-being and economic benefits to individuals and society more generally. By integrating additional evaluations of the socio-cultural benefits of trees urban forests, we have been able to provide additionality to the dominance of ecological approaches to urban forestry (Duinker & Greig, 2007; Conway, 2016). Community forestry in England differed as it was proposed as a mechanism to address landscape dereliction in post-industrial locations. Used as a regenerative tool, England's Community Forest partnerships worked with local government, developers and communities to reimagine the value of the landscape and used GI as a mechanism to promote investment (Blackman & Thackray, 2007; Kitchen, 2013). Greenways, garden cities and urban and community forestry have thus been instrumental in shaping the conceptual basis of GI and providing signposts to other forms of investment, i.e. low-impact development or landscape ecology principles.

In addition to these four key areas of influence, there have been a series of water and ecologically focussed concepts that have also helped to shape GI thinking (Li et al., 2005, 2020). The connective principles of links, hubs and nodes outlined in landscape ecology research have been a key driver of the spatial articulation of GI since its initial inception (Jongman & Pungetti, 2004). Moreover, the growth of ecosystem services thinking (and more recently Natural Capital and Biodiversity Net Gain practices) within GI research has provided an increased level of technical expertise with regard to environmental systems (HM Government, 2018; eftec, Environmental Finance and Countryscape, 2019). This has enabled GI advocates to consider the ways in which ecological functions work at different scales and what provisioning, regulating and supporting services, as well as the cultural benefits, they provide (Zuniga-Teran et al., 2020). However, the inclusion of detailed ecological perspectives has also been challenged as undermining the role of people and society in GI planning. Thus, a level of balance is needed to ensure that the four types of services and benefits noted above are met. Sustainable water management in the form of Water Sensitive Urban Design (WSUD), Sustainable Urban Drainage Systems (SUDS) and green stormwater management is also considered to hold a significant influence on the development of GI (Lashford et al., 2019). Although the most prominent focus of water-centric GI development lies in the USA, and more recently China, there is an appreciation that effectively managed water systems and the associated issues of provision and quality are core elements of GI practice. This has been critical to GI development in the USA, as it allowed advocates to generate funding via the delivery of the 1972 Clean Water Act. Similarly in China the central government mandate of sponge city development linked to urban sustainability and climate change mitigation has provided the framework (and associated funding) to deliver innovative GI in practice (Qiao et al., 2020).

In more contemporary GI research, there has been a visible increase in the use of alternative terminology to direct investment in environmental enhancement. However, the use of NBS, sponge city or blue-green infrastructure (B-GI) could all be considered to be derivations of GI as they draw on a comparable set of principles to direct investment (Wang & Banzhaf, 2018; Liao, 2019; O'Sullivan et al., 2020). This includes an increase in the size, diversity and accessibility of nature in urban settings, a consideration of environmental systems thinking and a promotion of multi-partner project teams to deliver multiple benefits to multiple stakeholders (Mell & Whitten, 2021). Current arguments for the use of ecosystem services or NBS as alternatives to GI may therefore be a matter of preference (Garmendia et al., 2016; Matsler et al., 2021). However, we could also propose that GI offers a more strategic oversight of development that draws on the principles noted above which are then delivered as NBS. Taking this idea further, we could suggest that NBS or sponge cities are the current elemental articulations of GI, whereas "GI" is the embedded knowledge, lineage and evidence base that enables stakeholders to deliver projects (Koc et al., 2017; Wang & Banzhaf, 2018).

1.10 The People, Policy and Practice Nexus

Central to the uptake of GI in mainstream landscape and urban planning has been the influence of strong advocate voices within policy and practice discussions (Mell & Clement, 2020). Organisations working with, and across, the natural and built environment have spoken in favour of investment in GI to a broad set of audiences. These include receptive stakeholders within the environment sector but also those historically deemed to be reluctant to engage with ecologically focussed issues, especially where additional economic costs are visible (Mell, 2021). This has led GI advocates to engage in an ongoing dialogue with stakeholders to examine what factors are limiting their acceptance or use of GI. In several instances a lack of robust evidence has reduced use, whilst in others the need to embed additional knowledge into existing practices has been deemed undesirable. Moreover, a shift towards an inclusion of GI in praxis requires a level of flexibility within policy structures to allow new ideas to be debated and permeate into political thinking (Finewood et al., 2019; Meerow, 2020). This is not always present, especially in locations where the approach to environmental management is deemed to be effective, i.e., in Germany (Hansen et al., 2019). Over the last 15 years, though GI has successfully been integrated into policy mandates in many locations, for example, in the UK, however, reluctance related to the terminological, political or economic uncertainty of GI means this is not the universal case (Li et al., 2005; Landscape Institute, 2013; Liquete et al., 2015).

Where success has been delivered, we can identify a greater level of understanding of the needs of a specific location, the options for development and the socio-economic and political context that a project lies within. Examples include the regenerative actions associated with landscape renewal in the Ruhr region and the delivery of the Landschaftspark Duisburg-Nord (Stilgenbauer, 2005; Cho, 2010; Mell, 2016).

Several of the chapters in this volume discuss the complexity of aligning policy and practice highlighting the potential limitations facing GI advocates as they attempt to embed the concept in localised thinking and action. However, there are also the thematic, spatial and political options open to practitioners, as they try to navigate these constraints. The chapter discussing the guiding of GI via a thematic framing of water management in Brazil by Pellegrino and Ahern is one example of this process. They, and others, examine the ways in which local practices can be shaped via the inclusion of additional evidence and best-practice guidance, although they and Sanchez et al. in their chapter in Arizona report on the effort, framing and negotiation needed to ensure that GI becomes a "go to" approach within planning.

Consequently, we must be considerate of the breadth of opinion related to what GI is, how it should be used and what issues it should address. This differs geographically, across disciplines and at various scales, all of which mean that advocates of GI need to be fluent in the linguistic gymnastics of practice in different places. The translation of meaning and application in Europe, North and Latin America and Asia, as discussed in the following chapters (e.g. Chap. 2 by Meredith Whitten), therefore requires careful consideration of what we mean when we use the language and terminology of GI and how this may present or limit opportunities for implementation and management.

1.11 Summary

The following chapters provide contemporary insights into the use of GI in a global context. They make links across terminology, disciplines, timeframes, scale and thematic approaches to investment and management and raise questions about best practice. What is common across all authors in this book is the depth of appreciation they provide to GI as a mechanism to address some of key issues facing landscape and urban planning in the twenty-first century, namely, ecological health, climate change and societal well-being. They do this by examining the ways in which GI, and its aligned concepts, are debated, framed and implemented in diverse locations around the world. Consequently, they provide a valuable addition to the research literature on GI and highlight opportunities for further research and practice. By exploring how GI differs between locations, how it has changed over time and how alternative users engage with the concept, each chapter supports the evolution of GI and its value in landscape and urban planning.

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Chapter 2
Engaging Resilience: Integrating Sociocultural Dimensions into Green Infrastructure Planning

Meredith Whitten

Abstract Green infrastructure is recognized for its holistic approach to planning. By integrating economic, ecological, and social aspects into planning policies and practices, green infrastructure provides both a conceptual framework and a practical planning tool for addressing complex, multiscale environmental problems. In addition to an interconnected, multifunctional spatial approach, green infrastructure also brings together disparate disciplines, providing a common language for dealing with contemporary challenges. Yet, despite the comprehensive approach, specific interests and expert knowledge can be privileged over others. In particular, scientific and ecological information can sideline input from local communities and residents, which is often considered subjective and difficult to measure. However, sociocultural considerations are central to green infrastructure's adaptive capacity and, thus, its ability to achieve resiliency objectives. This chapter explores how green infrastructure planning integrates differing perspectives, focusing on how citizen engagement can strengthen the role of sociocultural aspects in planning, designing, and delivering adaptable and resilient cities. Typically considered non-experts, local residents have their own expertise to offer, and green infrastructure can improve how this specific knowledge informs planning policies and decisions.

Keywords Sociocultural values · Community engagement · Participatory planning · Local and indigenous knowledge · Community-scale green infrastructure

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2.1 Introduction: Establishing Green Infrastructure

Twenty years ago, green infrastructure (GI) was a relatively unheralded concept rooted in landscape ecological theory (Roe & Mell, 2013) and conservation (Seiwert & Rößler, 2020). In less than two decades, though, the concept catapulted into mainstream planning as a tool invoked across countries, metropolitan areas, industries, and sectors to shape how cities are planned, designed, and experienced (Hansen & Pauleit, 2014; Mell et al., 2017; Roe & Mell, 2013; Voghera & Giudice, 2019). Driven by a heightened focus on improving the environmental, economic, and social resiliency of cities and regions through strengthening natural elements, green infrastructure presents myriad broadly appealing benefits (Matthews et al., 2015; Roe & Mell, 2013). Some of the benefits attributed to green infrastructure include reduced greenhouse gas emissions and climate change mitigation; enriched habitat and biodiversity; stormwater management and flood risk mitigation; improved air and water quality; enhanced access to recreation; urban cooling; improved health and well-being; increased property values and tourism revenue; reduced costs related to natural disasters and public infrastructure; enhanced social cohesion; and improvements in sense of place and quality of life (Benedict & McMahon, 2002; Gill et al., 2007; Kambites & Owen, 2006; Mell & Clement, 2019; Wright, 2011).

Benedict and McMahon's early and influential definition describes green infrastructure as "an interconnected network of green space that conserves natural ecosystem values and functions and provides associated benefits to human populations" (2002: 12). This seminal definition's simplicity and broad applicability has contributed to the concept's acceptance and adoption across varied disciplines. As laid out by Mell (Chap. 1), green infrastructure is characterized by several guiding principles: connectivity, multifunctionality, access to nature, integrated policy/practice, multidisciplinary collaboration, and an understanding of the socioeconomic and ecological benefits of effective landscape management (Mell & Clement, 2019). As such, green infrastructure refers to a range of green elements that deliver multiple benefits and that are strategically planned, managed, and connected at spatial and administrative scales (Matthews et al., 2015). Today, countries, regions, and cities across the world have adopted green infrastructure policies and strategies (Calvert et al., 2018; Wright, 2011).

Green infrastructure signifies "a dramatic shift in the way local and state governments think about green space" (McMahon, 2000: 4). It achieves this by going beyond ecological-focused planning and the social and aesthetic emphasis of conventional green space planning. These planning approaches traditionally have occurred independent from each other with "separate governmental entities and policies focusing on singular issues such as recreation, water or biodiversity" (Rall et al., 2019: 264). Instead, green infrastructure reconceptualizes parks, gardens, trees, verges, sustainable urban drainage systems, and other natural features as a strategic working landscape rather than as isolated, passive amenities (Whitten, 2020, 2022).

Further, green infrastructure serves as an organizing framework for connecting green elements across functional areas that previously had operated disparately, such as health, housing, and highways (see, for example, the London boroughs of Camden and Islington's integration of parks and local health strategies; FOL, 2021). This has reframed green space, going beyond conventional parks (Whitten, 2022) to consider a broad definition of natural and vegetated spaces as "critical scaffolding" (Eisenman, 2013: 298) rather than as a "cosmetic afterthought" (UKDoE, 1996: iii) or "frill" (McMahon, 2000: 4). This brings urban greening in line with how urgent contemporary environmental issues, particularly climate change and biodiversity loss, are addressed through an emphasis on the interrelationship among ecological, social, and economic considerations (Mell & Clement, 2019).

Through the foundational characteristics of interconnectivity and multifunctionality and its emphasis on intricately intertwined social-ecological systems (Hansen & Pauleit, 2014), green infrastructure has moved conversations "from siloed discussions of 'landscape' towards a collective, and in many cases co-produced, understanding of the environment as a multi-faceted entity that serves multiple ecological or socio-economic functions" (Mell & Clement, 2019: 9). This presents green infrastructure as having "the potential to offer win-win, or 'no regrets' solutions" (EC, 2012: 1), distinguishing it from the closely linked sustainability planning (Roe & Mell, 2013). Sustainability seeks to balance conflicting interests, yet has been criticized for perpetuating a nature-society dualism in urban planning (Talen & Brody, 2005), while green infrastructure emphasizes integration of disparate disciplinary and sectoral interests. Thus, sociocultural, ecological, and economic concerns are not competing, but rather being addressed concomitantly. Although subtle, this difference moves green infrastructure planning towards a more holistic and inclusive approach to building resilience, with the multiple functions it accommodates in aggregate producing a "synergistic effect that exceeds the sum of its individual merits" (Kim & Song, 2019: 4).

Yet, green infrastructure "has not come out of nowhere" (Wright, 2011: 1004). Rather than emerging as an entirely new concept, green infrastructure is regarded as a "hybridized concept" (Mell et al., 2017: 335) and "a melting pot for innovative planning approaches in the field of nature conservation and green space planning" (Hansen & Pauleit, 2014: 516). Indeed, green infrastructure can be considered as an evolution of planning narratives and approaches addressing a city-nature nexus, including Victorian parks (Wright, 2011), Howardian garden cities (Mell, 2008), and Olmstedian multifunctional urban landscapes (Eisenman, 2013). More recently, particularly in the USA, green infrastructure has developed from debates surrounding stormwater management (Mell et al., 2017) and greenways planning (Seiwert & Rößler, 2020), while Rosenberg "sought to redefine the public park as an extension of urban infrastructure" (Matthews et al., 2015: 156).

Indeed, the "meteoric" (Lennon, 2015: 958) rise of green infrastructure coincides with a larger "infrastructural turn" over the past two decades that challenges the meaning of urban infrastructure (Wiig et al., 2022). Rather than narrowly conceptualizing infrastructure as hard, gray, material artifacts, and systems, such as roadways and sewer lines, this infrastructural turn has connected wider networks of objects and services – including the “green and growing” (Gabrys, 2022: 14) – to the sociopolitical complexities of contemporary urban processes. In this regard, nature has become infrastructural (Gabrys, 2022; Nelson & Bigger, 2022). Fundamental to this repositioning of nature is its intersection with social systems (Hansen & Pauleit, 2014). People and communities shape and are shaped by infrastructural systems, and this extends to green infrastructure. As such, sociocultural dimensions are greatly entangled with the conceptualization of green infrastructure. Further, communicative and socially inclusive planning is central to a green infrastructure approach (Hansen & Pauleit, 2014), as green infrastructure remains the result of social processes and decisions (Meerow, 2020).

2.2 A Shapeshifting Concept?

Despite its increasing integration into planning policy and discourse, green infrastructure remains an elusive (Hansen & Pauleit, 2014) and “carelessly used” concept (Scott & Hislop, 2019: 177). This reflects ongoing difficulties in researching the concept (Mell, 2008), developing green infrastructure policies, and implementing green infrastructure in practice (Matthews et al., 2015). Much of the academic literature continues to be preoccupied with defining what green infrastructure means (Lennon, 2015), indicating an ongoing discomfort in pinning the concept down. Mell et al. observe that “there are currently as many interpretations of green infrastructure as there are people engaging with the concept” (2017: 335). Continuing conceptual shifts enable green infrastructure to mean “different things to different people, depending on the context in which it is used” (Benedict & McMahon, 2002: 12). These contexts vary not only across disciplines, but also geographically, with “localized interpretations” emerging (Mell et al., 2017: 333). While this flexibility provides opportunities for local context, local engagement, and local buy-in, a lack of definitional clarity can threaten adoption and consistent application of green infrastructure policies and practices, potentially undermining its effectiveness as a planning tool (Scott & Hislop, 2019). Thus, while the environmental, social, and economic meanings attached to green infrastructure continue to evolve (Wright, 2011), the concept’s ability to take hold in policy, practice, and research remains unsettled, as “new interpretations of green infrastructure are consistently being developed” (Mell et al., 2017: 336). As such, the part sociocultural attributes play in green infrastructure planning is constantly under development, as well.

Robust longitudinal studies of green infrastructure policy implementation and practical application have been slow to occur; thus evaluation has been limited to short- to medium-term impact (Mell & Clement, 2019; Willems et al., 2020). A lack of data and relevant case studies in some regions, such as sub-Saharan Africa, has limited evidence needed to integrate green infrastructure into policy and practice (du Toit et al., 2018; Lindley et al., 2018). The concept also has not had time to become embedded in planning processes in a way that ensures green infrastructure policies and practices are not simply conventional approaches with a new label or repeating unsuccessful efforts to integrate community engagement into planning processes. Indeed, green infrastructure can be delegitimized by a quickness to conflate it with green space more generally (Matthews et al., 2015).

Further, green infrastructure's attempts to shift the narrative around urban green space (McMahon, 2000) run up against powerful institutionalized amenity- and aesthetic-driven approaches to urban landscapes and green space planning (Di Marino et al., 2019; Whitten, 2020, 2022). As such, translating green infrastructure ideas and policies into mainstream planning practice, including incorporating localized sociocultural attributes, has proven challenging and is not yet supported with sufficient analysis of its effectiveness, including how sociocultural considerations are addressed (Calvert et al., 2018; van der Jagt et al., 2019). Indeed, gaps between policy rhetoric and implementation remain a challenge (Dempsey, 2020; Meerow, 2020), particularly between national policy and planning directives, and designing and implementing green infrastructure at the local level (Willems et al., 2020).

Further, lack of consensus around green infrastructure has been blamed on its ambiguity, leading to arguments that it is a "corruptible concept" (Wright, 2011: 1003) that can be manipulated and influenced, such as to advance political agendas (Breed et al., 2015). Claims that green infrastructure policies are adopted to green existing practices without impeding standard business practices can delegitimize green infrastructure, thus hindering efforts for meaningful application to address social and environmental challenges (Mell & Clement, 2019). As such, green infrastructure risks being a rebranding of existing neoliberal and development-centric initiatives rather than an innovative form of planning that meaningfully integrates community engagement (Matthews et al., 2015). Some policymakers and practitioners have expressed skepticism or caution about the relevance of the concept because, unlike gray infrastructure, it does not create direct financial revenue, such as taxes (Wilker et al., 2016). Difficulty directly capturing the benefits of investment in green infrastructure often leads to cuts in resources for urban greening (Wilker et al., 2016), particularly in the context of austerity politics (Mell, 2020; Whitten, 2019). Resources for engaging local communities and integrating their priorities can be particularly vulnerable to funding cuts and cost-efficiency measures. For example, community outreach officers serving as liaisons between local residents and a council's environment team were some of the first positions cut by London councils during the recent decade of austerity in the UK. Debate also has emerged regarding whether the scholarly proclivity for green infrastructure is reflected in mainstream planning practices (Di Marino et al., 2019).

However, the rush to embrace green infrastructure despite the lack of rigorous analysis of its impact may signal readiness for a "new analytical frame" to supplant long-held approaches to green space planning (Rutt & Gulsrud, 2016: 124), particularly involving disciplinary cross-pollination, administrative coordination, and collaborative community engagement. Conceptual ambiguity, some maintain, has buoyed this advancement, as it allows disparate interests to use a shared language to find common ground (Kambites & Owen, 2006; Wright, 2011). Lack of rigidity in green infrastructure as a concept more widely opens the door for local context and local involvement. More deeply embedding community engagement in a green infrastructure approach also presents the opportunity to harness the public's interest in a wider range of benefits, particularly relating to sociocultural factors.

2.3 Integrating Sociocultural Aspects

Sociocultural attributes are at the core of green infrastructure's multifunctional approach to resiliency (Mell & Clement, 2019; Roe, 2016). Yet, similar to experiences with sustainability planning, attention on social aspects lags behind that of economic and ecological considerations in both research and policy (Dempsey et al., 2011; Chan et al., 2012). Although sociocultural values are greatly entangled with humans' relationship with the environment, these values often are overlooked or poorly integrated into green infrastructure policies and practices (du Toit et al., 2018; OPERAs, 2016). Matthews et al. refers to "a schism between nature and culture" that has emerged as efforts to delineate green infrastructure have evolved (2015: 157). Social and cultural aspects are disadvantaged, in part, because their "nebulous" (Matthews et al., 2015: 157) values and "intangible dimensions" (Chan et al., 2012: 745) are intrinsically difficult to measure and economically value (EC, 2012; Rall et al., 2019).

Different communities may have distinct connections to the environment, such as for heritage or spiritual reasons. Trees and certain animals, for example, can have cultural or heritage value for some communities (du Toit et al., 2018). Rationales for why people attach specific values to the environment, including cultural heritage, community identity, aesthetics, and spiritual value, are rarely explored because they are considered "hard to capture and represent against other values" (OPERAs, 2016), causing them to be "rendered invisible" in planning (Chan et al., 2012: 745). Thus, benefits that can readily be quantified or presented in planning metrics, such as air quality, are incorporated into green infrastructure plans, while benefits from services such as recreation, inspiration, socialization, and educational opportunities go unmeasured (Campbell-Arvai & Lindquist, 2021; Rall et al., 2019). The scarcity of relevant data contrasts with "the rich levels of ecological, infrastructural and statistical information usually at planners' disposal" (Rall et al., 2019: 265). Thus, sociocultural values become sidelined by more technocratic and tangible management approaches (Matthews et al., 2015). This "critical gap" results in a "partially formed" (Rall et al., 2019: 265) planning approach, with "a downplaying of or disregard for cultural services and issues of 'community' interest" (Campbell-Arvai & Lindquist, 2021: 2).

Further, expecting green infrastructure to perform numerous functions, including sociocultural ones, can be unrealistic, particularly in dense cities. This can result from ambiguity of the concept of multifunctionality by planners (Hansen et al., 2019), as well as the oversimplified belief that green infrastructure can "have it all" (Horwood, 2011: 271) and is capable of universally satisfying demands or that "the more functions the better" (Hansen & Pauleit, 2014: 527). This suggests the various functions green infrastructure can perform are equal or can readily accommodate each other. However, in practice, conflicts arise, and different functions and benefits are emphasized (Madureira & Andresen, 2014), such as between food production and flood mitigation (du Toit et al., 2018). As such, green infrastructure planning continues to refine its focus (Jerome, 2017).

Green infrastructure also is hampered by long-standing tensions that exist between planning's competing priorities, particularly between growth and conservation (Campbell, 1996, 2016). Lennon (2015) asserts that green infrastructure is simply the latest effort to address larger debates on balancing environmental concerns with development in land-use planning policy. Meanwhile, Thomas and Littlewood posit that green infrastructure is a form of "ecological modernization" that provides a "means of lubricating the frictions found between economic development and environment-oriented strategies" (2010: 212). Efforts to define green infrastructure can be seen to emphasize economic benefits and, because "contested concepts are inherently political," those with more political power likely have more influence over how the concept of green infrastructure is interpreted and implemented in policy (Wright, 2011: 1010). Specifically, when held up against more powerful economic development approaches, green infrastructure is vulnerable (Mell & Clement, 2019). Indeed, Wright (2011) argues that claims that green infrastructure benefits everyone are superficial, while in practice socioeconomic interests supersede environmental ones. For example, the UK government has sought to address resiliency by increasing urban green spaces (MHCLG, 2019) and facilitating green infrastructure standards (DEFRA, 2018). Yet, at the same time, it has allowed residential development to bypass the planning process through permitted development rights (Ferm et al., 2021) as well as proposed reforming the planning system with a focus on "build, build, build" (MHCLG, 2020; UKPM, 2020). The heightened focus on the benefits of nature for health and well-being that occurred during the COVID-19 pandemic has emphasized the added socioeconomic value delivered via increased investment in nature (Mell & Whitten, 2021).

Policy tradeoffs between environmental priorities and urban development are prominent, including in the Global South (du Toit et al., 2018). Local authorities prioritize providing basic services over provision and management of green infrastructure, thus perpetuating a siloed approach. Economic interests "carry significant weight for the implementation of green infrastructure, especially in uncertain economic conditions when the state must facilitate economic growth and meet housing pressure" (Wright, 2011: 1011). Even use of the term "infrastructure" links the issue of urban greening to socioeconomic concerns, including economic development, leading Matthews et al. to conclude that green infrastructure is "essentially an economic case for greening" (2015: 157).

Further, at its core, green infrastructure planning is about land use, and the capacity to affect land-use decisions is essential for economic development, with land use integral to a city's desirability and productivity (Breed et al., 2015). Attempts to economically value green spaces and green elements, such as natural capital accounting, have become more embedded in decision-making (Chan et al., 2012). This coincides with the growing assertion that green space and ecosystem services should be reframed as an economic investment, and this has led to pushing green infrastructure to focus more explicitly on economic benefits (Mell & Clement, 2019). The focus on growth and development typically comes at the expense of ecological and sociocultural benefits, thus diminishing green infrastructure's multi-functional aspirations. Indeed, traditional accounting methods typically dismiss green infrastructure's broader societal benefits, such as public health and biodiversity gains, because they are not as readily determined as costs for green space management are (Scott & Hislop, 2019). As such, "we tend to value what is measurable rather than simply measure what we value" (Scott & Hislop, 2019: 177).

While debate regarding an economic emphasis co-opting green infrastructure's multifunctional principle continues, the concept's roots in landscape ecology and conservation can result in ecological functions and services dominating green infrastructure narratives. Environmental values and functions are core to Benedict and McMahon's foundational definition, and an environmental focus is considered fundamental to securing green infrastructure's objectives (EC, 2012; Wright, 2011). Indeed, stated objectives emphasize promoting ecosystem health and resilience, contributing to biodiversity conservation, and enhancing ecosystem services (EC, 2012). However, green infrastructure initiatives are criticized for narrowly focusing on ecological issues to the exclusion of multifunctionality (Lovell & Taylor, 2013). Privileging environmental aspects of green infrastructure occurs at the expense of sociocultural and political-institutional concerns (Chan et al., 2012; Matthews et al., 2015). Ecological issues are given more weight than sociocultural experiences, in part, because ecological data is more straightforwardly collected and used and can more readily be verified by planners and other practitioners (Faehnle et al., 2014).

Additionally, legislative requirements and other legal instruments can be interpreted as prioritizing environmental issues over sociocultural aspects. In Helsinki, for example, Faehnle et al. (2014) found that ecological matters were given precedence over community preferences because of environmental legislation, as well as the belief that scientific information outweighs resident experiences. This stance was strengthened by the argument that legislation requiring community input "does not specify how residents' arguments should be valued, [thus] ecological requirements tend to be stronger" (Faehnle et al., 2014: 175). Further, traditional planning practices, exacerbated by siloed thinking, often approach social and ecological processes as contradictory rather than "synergistic" forces (van de Jagt et al., 2019: 758).

Yet, sociocultural values should not be disconnected from ecological values (van de Jagt et al., 2019). The interplay between ecological and sociocultural aspects should inform green infrastructure policy development and practical implementation from the outset. In other words, green infrastructure planning should facilitate these functions interacting simultaneously and collectively adapting to change (EC, 2012; Mell, 2008). Indeed, adaptability is a structural strength of green infrastructure (Mell & Clement, 2019). The concept's intrinsic adaptability and responsiveness matters because improving the capacity of the landscape to adjust and respond to changes, such as those stemming from climate change and public health concerns, enhances long-term environmental, economic, and sociocultural outcomes (Matthews et al., 2015). Green infrastructure planning accommodates changes over time because an interconnected network delivering multiple functions and services can adapt better than a fragmented patchwork of individual green spaces can. Given unknown future conditions arising from multifaceted challenges such as climate change, public health, biodiversity loss, and food insecurity, green infrastructure's core principles of interconnectivity and multifunctionality, for example, offer a valuable adaptive strategy (Lovell & Taylor, 2013). Rather than contributing to urban resiliency by merely minimizing harm to environmental systems, green infrastructure's ability to adapt gives it the ability to improve or restore natural resources.

Sociocultural considerations are fundamental to green infrastructure's capacity to respond to rapid urban change. Dynamic urban change brings a constant churn of demographics, cultural backgrounds, values, attitudes, and preferences. As cities change, so do their sociocultural character, values, and relationships with the environment. Green infrastructure's ability to adapt to sociocultural change is as important as its response to environmental change (OPERAs, 2016). In Yesan, South Korea, for example, a green infrastructure plan was developed to adapt to changes stemming from depopulation (Orantes et al., 2017). Connectivity of the region's ecological and sociocultural characteristics was central to the plan, which will guide Yesan's future development. In particular, planners were conscious of not prioritizing ecological assets at the expense of sociocultural ones. The result was a multifunctional green infrastructure plan that allows for "creation of areas where people can directly experience nature and acquire sensitivity about their natural surroundings and the value and services they can provide for the everyday life" (Orantes et al., 2017: 15).

The influence of competing interests on green infrastructure policy development and practical implication is reflected in an emerging geographically distinct consensus, shaped by political and cultural narratives, which influence planning traditions (Mell & Clement, 2019; Voghera & Giudice, 2019). Indeed, rather than moving towards international consensus, discourse surrounding green infrastructure is becoming more regionalized and localized, reflecting variation in national and subnational planning systems (Mell et al., 2017). This is illustrated by the differing approaches used in the USA and the UK, both of which expressed an early acceptance for green infrastructure. Whereas in the USA green infrastructure focuses largely on ecological principles and benefits, the UK's process is rooted in a more socially inclined approach (Kambites & Owen, 2006). Similarly, in North America, emphasis is strongest on stormwater management, whereas in Europe an integrated approach to ecological and socioeconomic improvements serves as motivation (Mell & Clement, 2019). This calls into question green infrastructure's capacity for providing a comprehensive and unifying framework that accommodates competing perspectives (Matthews et al., 2015).

However, at the same time, change is heterogenous; thus geocultural characteristics vary across space and time and must be constantly revisited. For example, aging urban populations in the UK and Japan signal evolving demands on and connections to the landscape. To adapt, a green infrastructure approach would recognize the need to extract changing health and well-being benefits that landscape can provide (Roe, 2016). In addition to population and demographic changes, changes occur in information about and attitudes towards the environment, resulting in changes in values of and relationships with the environment (OPERAs, 2016). As such, community engagement is not limited to a one-time exercise, but rather green infrastructure requires ongoing participation (Willems et al., 2020). Further, the relationship between people and landscape is intrinsically reciprocal, with culture simultaneously changing landscape and embodying it (Nassauer, 1995). This "mutual moulding" (Roe, 2016: 5) is constantly being recreated. Disregarding the input of local residents, particularly regarding sociocultural concerns, can facilitate green gentrification and perpetuate the exclusion of some community members (Campbell-Arvai & Lindquist, 2021). As such, continuous engagement with local communities is critical to identifying and adapting to shifting sociocultural values and, thus, must be built into green infrastructure planning (OPERAs, 2016; Roe, 2016). Without doing so, green infrastructure's ability to realize its potential as an effective planning strategy to shape development and improve urban resiliency remains unclear (Rall et al., 2019).

2.4 Building Capacity Through Community

Inclusion and participation "will be crucial to the success of green infrastructure" (EC, 2012: ii), and sit alongside interconnectivity and multifunctionality as guiding principles of green infrastructure (Benedict & McMahon, 2002; Hansen & Pauleit, 2014; Roe, 2016; Wilker et al., 2016). Community input is vital for integrating how residents experience and value the local environment into green infrastructure decision-making (Faehnle et al., 2014). Further, involving residents in green infrastructure planning initiatives can improve community buy-in, bolster public support, and enhance the likelihood of long-term success (Campbell-Arvai & Lindquist, 2021). For example, input from urban residents regarding their perceptions and values is critical to the efficacy of green infrastructure as an adaptive response to climate change (Matthews et al., 2015). It also is recognized that community-led involvement is essential to supporting planners, designers, and other landscape practitioners to develop equitable "places that are accessible, meaningful and functional for local populations" (Mell & Whitten, 2021: 13).

For these values to inform planning policy and decision-making, they must be expressed and explored. Thus, a community-led, bottom-up approach to participatory planning must underpin green infrastructure policy and practice (Ferreira et al., 2020; Mell & Whitten, 2021). Approaches that are more participatory are increasing, although scope remains for local governments and other entities to more readily embrace local knowledge in green infrastructure planning (Mell & Whitten, 2021; Willems et al., 2020). As green infrastructure and its focus on resilience become more prominently embedded in planning processes, cities are prioritizing active community participation to improve green infrastructure decision-making processes (Campbell-Arvai & Lindquist, 2021; Voghera & Giudice; 2019). Community-led engagement that occurs during initial stages of strategic planning and development, rather than seeking community input once decisions have been made or options narrowed, strengthens and elevates the influence sociocultural aspects have on using green infrastructure planning to build resilience.

For example, the city of Aarhus developed a master plan to guide transforming the monofunctional Gellerup housing estate – the largest social housing complex in Denmark – into a multifunctional urban area. More than 12% of the budget was allocated to developing urban green space (Hansen et al., 2017). With 79% of Gellerup's residents coming from non-Western countries, engagement in traditional participation schemes were not effective. Instead, the city turned to participatory workshops, "look-and-learn" visits, and walking tours with a range of residents, including women and youth organizations to engage with residents "from the inside out" (Hansen et al., 2017: 75).

Although local governments may have responsibility for delivering green infrastructure, its design and implementation are co-produced within a network of stakeholders (Willems et al., 2020). As such, green infrastructure's adaptability is reliant on a collaborative, socially inclusive planning process that prioritizes stakeholder and community engagement (Rall et al., 2019; van der Jagt et al., 2019). Citizen engagement can capture public attitudes and preferences regarding qualities or features of nature and urban greening to guide design and management decisions. As such, "profound levels of participation" (Willems et al., 2020: 24) are needed for green infrastructure planning, and "all groups of society should have a say in its planning and implementation to ensure that it meets their requirements" (Wilker et al., 2016: 230). Community collaboration and engagement also is needed to ensure that easily quantifiable benefits are not privileged at the expense of sociocultural benefits, such as cultural expression, valued by local residents (Campbell-Arvai & Lindquist, 2021). In particular, local and indigenous knowledge should be included in green infrastructure decisions (Ferreira et al., 2020).

Sociocultural aspects of green infrastructure planning are heavily context-dependent (Faehnle et al., 2014; Wilker et al., 2016), and, thus, community engagement at the local – even hyperlocal – scale is crucial for green infrastructure's success at a broader network scale (Kati & Jari, 2016). Indeed, a policy or benchmark should acknowledge that green infrastructure must "reflect and enhance the local character and priorities of the area for it to be successful" (Calvert et al., 2018: 570). For example, local residents can provide insights on "what kinds of places and routes different groups of residents find pleasant, calming, inconvenient, scary etc., which activities they appreciate, how the environment supports or hinders these activities and what kind of futures the different groups find worth striving for" (Faehnle et al., 2014: 172). Involving local stakeholders to form a "community of practice" could strengthen and contribute "indigenous knowledge of the benefits of traditional African garden forms," which is critical considering gardens traditionally have served as some of the most bio-culturally diverse spaces in a city (Lindley et al., 2018: 333). In contrast to traditional top-down decision-making approaches, community-focused input can improve conditions for development of green infrastructure (Wilker et al., 2016).

While the relevance of residents' values and preferences regarding the environment "is a serious issue in planning practice" (Wilker et al., 2016: 230), embedding community participation in green infrastructure planning and decision-making is difficult (Ferreira et al., 2020). In part, local community involvement remains "rarely adopted" because of the belief that "multi-stakeholder initiatives slow down urban planning and policy development processes due to a lack of consensus and different sectoral interests" (Ferreira et al., 2020: 2). Seen as subjective, resident and non-expert stakeholder input is often dismissed in favor of objective or nonpolitical knowledge from professional and scientific experts and disciplinary perspectives (Faehnle et al., 2014; Mell & Clement, 2019). As such, many green infrastructure projects continue to be top-down or expert-led initiatives (Campbell-Arvai and Lindquist, 2021), fitting with larger challenges in involving local communities in decision-making involving natural resources (Shandas & Messer, 2008). Local community values and input drawn from residents' experiential knowledge is challenged by the dominance of ecological information and, thus, is not recognized as relevant information in planning processes (Faehnle et al., 2014). Methods of community participation also may not fit with approaches to accessing technical experts (Shandas & Messer, 2008). As such, sociocultural concerns and needs voiced by local residents are disadvantaged compared to ecological and economic knowledge from scientists and other stakeholders (Faehnle et al., 2014). In particular, input regarding sociocultural considerations runs the risk of being a public participation tick-box exercise (Wilker et al., 2016). For example, in an analysis of 20 European countries, Hansen et al. (2016) found that citizen participation efforts for green infrastructure planning tend to be focused on efforts to contact stakeholders rather than on ensuring stakeholders are actually engaged and their input taken into consideration. As such, "it remains unclear … whether input produced by residents is regarded as relevant in the making of influential policy choices, such as choosing which ecosystem services and benefits should be considered" (Faehnle et al., 2014: 172). Further, green infrastructure planning initiatives that marginalize communities by prioritizing expert-driven and top-down approaches miss the fundamental principles of green infrastructure, namely "the establishment of inclusive and multifunctional urban greenspaces that are sensitive to the needs of users" (Campbell-Arvai & Lindquist, 2021: 9).

Yet, the perspective "of those who live, work and enjoy themselves, suffer or invest in a place, those who manage it, argue about it, and get involved in collective action on its behalf" (Healey, 2008: 448) is essential for adapting planning, including green infrastructure planning, for sociocultural changes (Wilker et al., 2016). This "intimate knowledge" of local values may be "sensitive territory," but including it is vital to decision-making and the legitimacy of green infrastructure planning (Chan et al., 2012: 746, 755). Local landscapes also provide "an understandable focus for community action" (Shandas & Messer, 2008: 415). Contrasting with ecological provisioning and regulating services, evaluating sociocultural attributes relies on understanding specific contexts and the cultures of local communities (Faehnle et al., 2014). Particularly in urban contexts, where green infrastructure implementation features more prominently, a disciplinary expertise-centric perspective can actually impede sustainable planning approaches (Mell & Clement, 2019). Local stakeholders' expertise, however, can advance understanding and, ultimately, the effectiveness and viability of green infrastructure efforts (Faehnle et al., 2014; Wilker et al., 2016). Community support is vital for social sustainability of green infrastructure features, but to achieve such sustained buy-in, these features must reflect the context of the local community (Campbell-Arvai & Lindquist, 2021).

As green infrastructure continues to evolve, recognition of the importance of community-scale green infrastructure sites in a multiscale green infrastructure approach has evolved. Small-scale green infrastructure planning initiatives complement projects at the strategic scale, underscoring opportunities for and contributions of active community-level engagement (Jerome, 2017). In Utrecht, The Netherlands, local residents have become actively engaged in Neighbourhood Green Plans, which provide a means for locals to contribute ideas for green space projects (Hansen et al., 2017). Feasible projects are connected and form a Green Plan, which local residents then help implement and maintain. A focus on the community scale may seem in conflict with or counterintuitive to green infrastructure's principle of taking a comprehensive approach to green space planning (Wilker et al., 2016; Rall et al., 2019), yet this is central to green infrastructure's adaptability. Economic and ecological valuations and outcomes may be more consistent across contexts, but sociocultural variation requires awareness of and sensitivity to specific situations. Failure to integrate sociocultural values through participation can result in disputes and disengagement, thus impeding green infrastructure's resiliency objectives (OPERAs, 2016). Chan et al. (2012) caution that omitting sociocultural values also can result in negative and unintended consequences that undermine a project's green infrastructure goals. As such, green infrastructure planning must ensure sociocultural values are "well-represented in techno-ecological or cost-efficiency analyses" (Kati & Jari, 2016: 544).

Indeed, just as disciplinary cross-pollination is essential for facilitating change and developing green infrastructure as a concept, community participation is needed to change institutionalized governance structures, shape debate, and influence implementation of green infrastructure planning (Mell & Clement, 2019). As such, knowledge is co-produced through disciplinary expertise and non-expert stakeholder discussions regarding scientific and social data, and cultural preferences. This is dependent on "integration of non-expert stakeholders embedded in the communities of practice where green infrastructure is being implemented" (Mell & Clement, 2019: 8–9).

Community engagement also risks occurring too late in the planning process to have influence. Participatory approaches should occur in the early stages of green infrastructure planning (Shandas & Messer, 2008; Wilker et al., 2016). In particular, identifying sociocultural values through stakeholder engagement should occur before making concrete land-use or management decisions, as this improves collaboration, leads to more sustainable solutions, and enhances the adaptive capacity of ecological and social systems (Kati & Jari, 2016). For example, performative participation, a practical, hands-on focus on designing and implementing green infrastructure, may be a more impactful approach to community engagement when addressing sociocultural aspects in green infrastructure planning. However, such an approach cannot be added into later phases of green infrastructure planning (Wilker et al., 2016).

While the contributions and value local green infrastructure initiatives can add to urban resiliency continue to be explored, the strategic network perspective fundamental to green infrastructure should not be sidelined. Small-scale green space and green elements have social value, but significant ecological challenges, such as dramatic loss of urban biodiversity, need larger-scale solutions that green infrastructure can facilitate. Indeed, the network perspective at a larger, landscape scale "is helping to modernize environmental policy" (Mell & Clement, 2019: 8). Localized, community projects can inspire broader efforts that are replicated throughout an urban area, enabling resilience or leading to transformation at a larger scale. And, by being engaged in decision-making processes, community members can strengthen understanding of the "connection between their action and the health of the environment" (Shandas & Messer, 2008: 416). As such, planners must maintain awareness of "the importance of green infrastructure from a human perspective" while balancing and connecting small-scale, community-focused green infrastructure initiatives with the need for a larger network of green infrastructure to deliver the ecological, economic, and sociocultural functions required for urban resilience (Mell & Clement, 2019).

2.5 Conclusion

Despite becoming increasingly integrated into planning narratives over the past 20 years, green infrastructure remains an evolving concept. Its uptake, however, recently has accelerated. This "meteoric" rise in policy and planning discourse has provided opportunities to move away from outdated planning approaches and instead reflect contemporary challenges and attitudes toward integrating nature into cities. Green infrastructure's principles of connectivity, multifunctionality, and adaptability have advanced the concept in a period of urgency for human and ecological health. Yet, the concept also suffers from growing pains, particularly definitional fragmentation and challenges integrating subjective knowledge. There also have not been opportunities for longitudinal impact assessments, particularly related to sociocultural aspects of green infrastructure.

Green infrastructure approaches tend to see ecological and economic considerations dominate, in part because they are more readily identified and measured, with relatability across scales, contexts, and jurisdictions, particularly compared to heavily contextualized social and cultural aspects. As such, sociocultural considerations have been slower to be integrated into green infrastructure planning. Yet, sociocultural issues are greatly entangled with ecological and economic functions, as well as forming a central aspect of green infrastructure planning on their own. Thus, focus is increasing on social and cultural aspects. This is facilitated by engaging local communities in participatory planning early in planning processes. Adaptability is particularly relevant, as changing urban contexts – including changing demographics, values, interests, and awareness, as well as changes in the physical built environment – are reflective of sociocultural changes. To develop a responsive green infrastructure approach, engaging the community through a bottom-up approach is central to building resilience, as well as to addressing processes of green gentrification.

Yet, research has been relatively neglectful of participatory green infrastructure planning (Willems et al., 2020). This is particularly the case for citizen engagement in later stages of green infrastructure – such as maintenance – that remain under-researched (Willems et al., 2020; Jerome et al., 2017). As green infrastructure continues to evolve and become further embedded in planning systems, more attention should be given to the sociocultural characteristics, values, and experiences of residents who make up diverse communities where the impacts of green infrastructure will be felt.

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Chapter 3
Green Infrastructure in Landscape Planning and Design

José Fariña Tojo and Emilia Román López

Abstract Landscape and Green Infrastructure are two concepts that have not yet found their perfect fit. In the following pages, we will present some of the methods we are currently trying in order to achieve a smooth coexistence between the two concepts. Actually, in spite of having approaches, tools and methodologies that can be considered well-established, defining 'landscape' still poses a challenge, since many knowledge areas (from geography to aesthetics) adopt this term as one of their own. The same cannot be stated about the Green Infrastructure concept which, after a quick evolution, enjoys a certain consensus. On the one hand, up until now, landscape has been understood as being a part of Green Infrastructure; and on the other hand, the latter has been understood as a tool (a very powerful one, admittedly) for certain landscape studies and plans. This paper argues that both approaches are valid, as long as the specific scale and site situations are considered.

Keywords Green infrastructure · Lanscape · Territorial plannig · Urban design · Structure · Scale

3.1 Introduction: Establishing Green Infrastructure

The different approaches that could be used to relate both concepts were already being critically considered at the I Colóquio Ibérico de Paisagem, the international congress held in Sintra, in a paper titled Infraestructura Verde y Paisaje presented by one of the authors of this text (Fariña, 2018). Essentially, two clearly differentiated

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lines can be distinguished: firstly, that of those who understand Green Infrastructure as the modern way of understanding landscape planning, in which case the three basic principles would be multiscale intervention and planning, sense of place and multi-functionality. This idea supports the interpretation of authors including Hansen and Pauleit and how they recognise the conceptual and practical values of Green Infrastructure. Sometimes other characteristic features are also added, such as strategic planning, or inter- and transdisciplinary features. It could also be argued that within such a discussion that the 'Landscape' is a further example of an 'ecosystem service', which could be used to promote a Green Infrastructure strategy (Hansen & Pauleit, 2014).

The second approach would be the one proposed by those who understand Green Infrastructure as a tool for landscape planning, a particularly important tool, but, after all, subordinate within the corresponding landscape plan. For example, the Valencian Regional Government's Department of Territorial Policy, Public Works, and Mobility state that: 'Green Infrastructure is organised on different scales: One of the key aims of the Landscape policy is to define the Green Infrastructure of the Valencian Community, as an interconnected network made up by the greatest environmental, cultural and visual value landscapes that will become the basic ecological structure of our region' (Muñoz & Domenech, 2012, 30).

For this autonomous community, Green Infrastructure is formed by the network of Landscapes of greatest value in its territory. Tom Turner, when referring to the planning of London's green spaces, goes further, saying:

> And how should this category of urban planning be called? "Green" is almost acceptable if it is used in both senses, but I doubt if this is possible and the word is too descriptive to serve as a planning objective. "Infrastructure" is also a utilitarian word, which is both an advantage and a disadvantage. I think about the activity as "landscape planning", because the aim is to make London a great urban landscape, incorporating a wide range of aesthetic, ecological and functional objectives. (Turner, web Landscape Architects Association, 2017)

It should be noted that Turner is talking about the super-urbanised London. However, these approaches are very general. The text that follows proposes an approach to this relationship based on two basic elements: the scale and the site.

We start by arguing that this relationship cannot be the same in an urban centre as in a biosphere reserve, nor on a scale of 1/500 or 1/50,000. We will see through this paper if this is the case. It is essential to start by explaining the different approaches in both concepts and then move on to examine the relationships between them. So, firstly, we will study those basic elements that define Green Infrastructure and landscape, as we understand them. Next, we demonstrate the different form of behaviour that occurs, according to the situation and the scale when using these concepts. Finally, we discuss whether Green Infrastructure is just another tool for planning the landscape, whether the landscape is just a means to an end for Green Infrastructure or whether, in fact, different situations occur according to the specificities of that place and the scale of planning and/or management.

3.2 Basic Elements of a Green Infrastructure

The concepts of Green Infrastructure and landscape are polysemous ideas. There are vastly different approaches to them, and it is essential to establish, prior to the analysis of the relationship between them, which is the starting point. Green Infrastructure is however a much more recent concept than landscape and could be considered easier to define. Moreover, a certain convergence between the different approaches is being consolidated within thinking on Green Infrastructure (Fariña, 2018).

As we will see, the Green Infrastructure expression has been linked for quite some time to that of 'networked natural areas'. At the end of the nineteenth century and, above all, at the beginning of the twentieth century, ecological awareness began to have a certain social impact (Compte, 1999). During this time, national parks emerged as areas of natural territory to be preserved, as they constituted unique and exclusive ecosystems (White, 1985). The first one to legally obtain a protection status was Yellowstone, which is mostly located in the state of Wyoming, but also in Idaho and Montana (Sanz, 2012). In 1870, Nathaniel Langford and Cornelius Hedges visited this area and noticed its great interest. This interest was threatened by the settlers who, at that time, were spreading over the 'unexplored' areas of the United States. Their proposal was to legally exclude these lands from the possibilities of colonisation (Olmsted, 1865). On March 1, 1872, under the presidency of Ulysses S. Grant, the US Congress approved the declaration of Yellowstone as the first national park in the world. Yosemite had tried it before but failed until 1890 (Culpin, 2003).

This way of preserving a territory, through controlled tourism, teaching and research by the scientific community and trying to reconcile its natural values with its enjoyment by the population, is important because it will be seen how this approach will later lead to a way of understanding nature as a provider of so-called ecosystem services. This can be deducted, among others, from the scientific-technical basis for the State Strategy for Green Infrastructure and Ecological Connectivity and Restoration (Valladares et al., 2017).

As in Yellowstone and Yosemite, and not only in the United States, but throughout the world, an interest in preserving areas of the territory for their natural values became an established, if contested, norm in some locations (Hays, 1959). In this way, a multitude of protected areas emerged: in some cases, such as in the case of parks, with the possibility of use and enjoyment by population; in others, avoiding anthropic interference, as happened in the so-called nature reserves. In this way, significant areas, in many countries, were, and continue to be, legally excluded from urbanisation processes. It soon became clear that the problem was that these areas of nature, as islands in the middle of anthropized areas, behaved like isolated relics, progressively degrading themselves, losing biodiversity, and becoming less resistant to external aggressions. The concept of networked nature areas emerges then from the need for all these nature areas to be physically connected to each other, so they would no longer be isolated islands (Cranz, 1982).

According to Benedict and McMahon (2002), the concept of Green Infrastructure was originally proposed in the United States to address issues of nature area fragmentation and to assist in the management of flooding due to poor stormwater management practices. One historical example of this was in 1879, the Boston Parks Commission consigned F. Law Olmsted to create a network of parks. The result was the Emerald Necklace, a set of urban green areas linked together by connectors (Stevenson, 1977). In 1864 Olmsted had taken part in the commission in charge of organising the natural environment of the State of California once Yosemite Park was ceded to that state (Olmsted, 1865). The fact is, that at the end of the nineteenth century, the concept of Green Infrastructure (although not the expression) began to make its own path, almost at the same time as the creation of legally preserved natural areas.

The network of natural areas for flood control was considered from the outset of Green Infrastructure planning. The example of the Emerald Necklace of the city of Boston illustrates the system ideal via its connected network of urban parks. One of the main objectives of this project was to achieve a reduction in flooding. This approach could be classified as the 'American approach' because it was in North America that all these methods took place and the ongoing focus on water management is most frequently seen in the United States (EPA, 2018). Still today, for the American Planning Association, the concept of Green Infrastructure refers to 'small-scale green systems designed to be urban storm water management infrastructure' (Rouse & Bunster-Ossa, 2013, 22). Even according to Firehock (2010), the first time the term is used was a century later, in 1994, in a report delivered to the Governor of Florida containing the idea of expressing that natural systems are only a part of our infrastructure.

However, the concept of networked nature areas and parks, which (among other uses) has a utility for flood control, has now been superseded by the introduction of 'ecosystem services'. In a 1997 publication entitled *Nature's Services: Societal Dependence on Natural Ecosystems*, Daly proposed an approach that makes possible a very didactic understanding of how ecosystems contribute to the possibility of urban life (Daily, 1997). There are quite a number of definitions of this concept, but they are all contributions which argue that the natural environment adds to our quality of life, place and environment. Ecosystem services for many authors have, as a consequence, become a basic part of the Green Infrastructure core. Thus, in 2013 the European Union, with the Communication entitled: 'Green Infrastructure: Enhancing Europe's Natural Capital', proposed the following definition:

> A strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. It incorporates green spaces (or blue if aquatic ecosystems are concerned) and other physical features in terrestrial (including coastal) and marine areas. On land, Green Infrastructure is present in rural and urban settings. (European Commission, 2013, 3)

This European vision of Green Infrastructure is important because it is comprehensive in many different aspects. Furthermore, although Blue Infrastructure has already been mentioned as being included but not a primary concern, aquatic ecosystems are integrated into their thinking. The focus is however not only on marine or terrestrial but also on the continuum of 'rural and urban environments' (European Commission, 2013, 3). This idea would lead to the inclusion of agricultural areas, as well as cities where they are considered natural or semi-natural areas and other environmental elements.

This wide-ranging vision of Green Infrastructure is currently being imposed in almost all parts of the world. However, we also consider the urban setting of green areas as a network, physically connected in other areas. Additionally, peri-urban areas, relatively natural, including those dedicated to agriculture and proximity livestock, are included in this classification and those less anthropized areas far from urban centres. This vision has led us to talk about integrated Green Infrastructure as a system that allows us to consider the entire territory from a more ecological than anthropic perspective and which should condition how we approach traditional territorial planning (Beauchamp & Adamowski, 2013).

Although its relationship with the landscape will be analysed later, at this point it is important to note the sense that there will be confrontational positions on the one hand from the subject, and on the other from the aims that Green Infrastructure can achieve, and, therefore, from the tools to be used. To complete the study of the relations between both, it is necessary to specify how ecosystem services are shaping Green Infrastructure thinking and practice (Viota & Maraña, 2010). There are different classifications of ecosystem services. Potentially the most frequently used is the Millennium Ecosystem Assessment (2005). In this evaluation, additional to the supporting ecosystems themselves, they are classified into the three main classic groups: supply ecosystems, regulation ecosystems and cultural ecosystems.

Supply services are those that contribute directly to human well-being. These are fundamental services because they can include water, both for human consumption and for agricultural and industrial uses; foodstuffs from agriculture, livestock or fishing; also, those foods obtained directly from natural ecosystems; medicines such as those obtained from wild plants; raw materials of geological or biotic origin; renewable energies; and even genetic information used in biotechnology.

The second type of services are those that provide regulatory services and functions. Contributions to human welfare here are indirect, but no less important. Although there are many services, for the purpose of this chapter article, we will just focus on the following: biological pest control; erosion control; pollination; soil fertility; climate and air quality regulation; water regulation (including flood control, which we have already seen was fundamental in the consolidation of the concept of Green Infrastructure); and soil, air, and water purification.

However, the ecosystem services most related to the topic of Green Infrastructure and Landscape are potentially the cultural ones. That is, according to the definition of the Spanish Millennium Survey (EME, 2011, 27): 'those intangible contributions that people obtain through their straight experience with ecosystems and their biodiversity'. These include recreational activities; environmental education; ecotourism; ecological and scientific knowledge; identity and sense of place; and, most importantly in this case, enjoyment of the landscape. On a large scale, it can be argued that all ecosystem services are suffering from significant decline in recent years, as can be taken from the aforementioned Spanish Millennium Survey. Regarding landscape in relationship with their aesthetic elements, the Millennium Ecosystem Assessment report affirms:

> Demand for aesthetically pleasing natural landscapes has increased their value in line with increasing urbanisation. There has been a decline in the quantity and quality of these areas to satisfy this demand. A reduction in the availability and access to natural areas for urban residents may have significant detrimental effects on public health and the economy. (EME, 2011, 287)

3.3 Different Approaches to the Concept of Landscape

Different approaches to the concept and study of landscape carried out by architects, geographers, ecologists, psychologists and agronomists, for example, reinforce the need to generate intermediate forms of knowledge, which transcend the limits of the various disciplines. Thus, there are multidisciplinary methodologies, where specific elements, ideas or concepts which converge in the idea of 'landscape' are provided. There are also interdisciplinary approaches for which exist a transfer of methods and an organisation of knowledge, towards a shared and hermeneutic interpretation of the landscape. Evidently, the study of landscape must have a transdisciplinary character, linked, according to the European Landscape Convention (Council of Europe, 2000), to policies for its protection, management and planning. All these, using necessarily a comprehensive vision. This holistic consideration of the landscape has gradually engaged with other methodologies that have utilised the subject area in different ways.

Before getting deeper into the different definitions, it is informative to review the concept of landscape itself. According to the Royal Academy of the Spanish Language (RAE), the term landscape comes from the French word 'paysage', whose semantic root is linked to nearby land (pagus, land) and has the following meanings (RAE, 2014):

> Part of a territory that can be observed from a certain place;
> Natural space admirable for its artistic aspect; and
> Painting or drawing that represents a landscape (admirable natural space).

The last two references suggest that the term landscape is mainly associated with natural spaces. However, according to the European Landscape Convention, Article 1, Definitions: 'Landscape means an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors' (Council of Europe, 2000, 2). In other words, the Convention also covers anthropized landscapes, such as urban sceneries. This idea is reinforced in Article 2, which specifies the scope of action:

> this Convention applies to the entire territory of the parties and covers natural, rural, urban and peri-urban areas. It includes land, inland water, and marine areas. It concerns landscapes that might be considered outstanding as well as every day or degraded landscapes. (Council of Europe, 2000, 2)

This confirms that landscape is not only associated with natural areas, but also with urban, peri-urban and rural areas. In fact, it is not only related to 'admirable natural areas' and exceptional ones, as indicated in the meanings of the RAE, but also to everyday or quotidian, and degraded landscapes, which are very present in our territories.

Another important issue raised from the definition of the Convention reflects on the fact that for there to be a landscape, it is necessary not only for the existence of a territory but also the presence of an observer. This view was outlined by Turri (1998, 14) who noted:

> Where there is no man who knows how to watch and being aware of himself as a presence and as a territorial agent, there would be no landscape, but only nature, mere biotic space, until making us consider that, between the two theatrical actions of man, acting and watching, the second emerges to us as more important, more exquisitely human, with its capability to lead the previous one.

This suggests a high level of subjectivity and describes 'interpretation' as a key component, since it depends on the knowledge and lived experience of the spectator, regarding the landscape that they observe and, in some cases, which they also create and maintain. Moreover, people can, and should, be considered agents who transform territory whilst continuously observing the environment around them, thus promoting close links between contemplation and the transformation of the landscape. Again, Turri (1998, 13) discusses this suggesting that:

> The notion of landscape as a theatre sustains that man and society act towards the territory in which they live in a double way: as actors who transform, in an ecological sense, the framework of life, imprinting on it the sign of their own action, and as spectators who know how to look at and understand the meaning of their procedure in the territory.

In recent decades, landscape debates have been dominated by two clearly distinguished positions. The first maintains that landscape is a cultural construct, so the culture of a specific society is the instrument that shapes the territory over time. In this sense, the rudimentary elements of the landscape are the physical environment; human action, which modifies the environment for a certain purpose; and the specific activity carried out, which is related to life habits, economic activities, culture or beliefs. Back in 1925, Carl Sauer had written: 'Culture is the mean, the natural area is the environment, and the cultural landscape is the result' (Sauer, 1925, 23).

The second interpretation is focussed on a more scientific and physical-biological-based understanding that establishes a holistic approach to answer the complexity of systems and subsystems that structure the landscape. It enunciates the idea of landscape from an ecological perspective, expressed as the 'spatial translation' of a set of interacting ecosystems. Thus, landscape links spatial structures to ecological processes (Forman & Godron, 1986), concepts which are more intricately related to what is currently understood as Green and Blue Infrastructure.

Within this discussion, if we include the definition of the Convention of any part of a given territory as it is perceived by the population, the landscape then could be understood as a set of perceptible components in the shape of a panorama or scene (phenosystem), leaving background as the most difficult complement to observe, which provides a complete description of the ecological geosystem (cryptosystem) (Fariña, 2001).

Therefore, via our conceptions of the landscape, the existence of the human observer is always implicit, because it is what infuses it with the character of a cultural concept, since observation depends on the personal and collective history of the subject and breakups from the observed object (in this case the territory), which has its own existence. As such, there is no landscape without an observer. In contrast, although there is no human observer, a territory made up of a group of elements and a collection of relationships between them (an ecosystem) can exist, which is the landscape basis, when the observer emerges.

For some years now, in addition to these cultural and scientific approaches to the landscape, there have been others, more related to quality of life and benefits that they provide. In this sense, the landscape is seen as a place where human relations are established, which is also perceived and inhabited and additionally has natural, cultural and identity values which are very relevant to the citizens' health. This process of value attribution was outlined by Menatti who stated that: 'The landscape, then, is not something natural, trivial or simply aesthetic in the classic sense of the word; it is something that dynamically constructs us always' (Menatti, 2018, 60).

Many environmental psychology studies have also demonstrated the positive and healing effects, as well as the reduction of stress, that landscapes produce in people linked to aesthetic quality and naturalness (Kaplan & Kaplan, 1989; Ulrich et al., 1991). This issue, which has also been developed within the medical geography and architecture literature through, for example, therapeutic landscapes and gardens, is causally related to Green Infrastructure and services provided by ecosystems. By the same indicator, a degraded, polluted or abandoned landscape could lead to negative health effects and even a sense of insecurity or lack of identity. Consequently, the importance of environmental restructuring and improvements in the aesthetic quality in a landscape, both natural and urban, serve to improve a community's quality of life.

3.4 Locations and Scales

A set of important queries are raised when we focus on location, both, as a set of individual areas and as connectors. These include: Is it the same concept if we use the expression Green Infrastructure when we refer to an interconnected network of natural spaces that have been vaguely anthropized, or not at all, or when those same spaces that we connect, for example, gardens, are urban elements?

Moreover, would we be talking about the same concept, when we propose a peri-urban green ring and compare it with the previous situations? As we have seen, one of the basic functions (separately from the support functions, related more to ecological issues) of the Green Infrastructure is the provision of ecosystem services. Using this as a starting point, we could change the previous questions to: Are the same ecosystem services a priority in the case of highly anthropized areas besides others which are not?

To answer this question, it is necessary to know what those services are. If we start with the case of urban areas, it seems that the different authors agree, as outlined in the "Guide to Green Infrastructure in Municipalities (Spanish Federation of Municipalities and Provinces)":

> 'The work range of green infrastructure is multiscale, it includes the landscape scale at local, regional and national level, and is driven by a public process of wide scope, which converts itself into an operational strategy to protect an ecological network of land conservation, but also to offer other services such as cultural services, especially important in urban environments'. And further: 'Green infrastructure elements in cities and towns provide multiple benefits, including improved health and well-being, shade, thermal regulation, cleaner air and better water quality. Ecosystem services are high profiled and there is growing recognition of the relationship between the use of green infrastructure elements and improved public health and well-being'. (Calaza, 2019, 21)

It seems, therefore, that in the case of urban Green Infrastructure, ecosystem services take on special relevance and, mostly, those of a cultural and health and population well-being nature (Calaza, 2019). At the other end of the continuum are the less transformed nature areas cases, in which the priority issue would be ecological and would be related with biodiversity and resilience. In this case the ecosystem services, such as those of regulation, control, recycling and waste treatment, would have priority and that would be ecological, although those of another type, such as food, genetic or cultural production would also have to be considered, but subordinated to the preceding ones (Constanza, 1997). Biodiversity and resilience issues would therefore be critical.

A different instance would be peri-urban areas that would be in the middle grounds, located between urban and more natural sites and where purely ecological and ecosystem services considerations would depend on each specific situation. In the guide cited above, it can be read:

> In the same way, peri-urban areas represent transition zones with more, natural or agroforestry exploitation areas, which are zones of contact and interaction between different ecosystems elements, ecotones, which are especially important because they work as buffer zones, and where there are a high number of peri-urban forests and parks that provide a large number of services to the population. (Calaza, 2019, 21)

In order to clarify the topic, which one can begin from, there are three basic situations to address in the relationship between Green Infrastructure and landscape in an operational mode. The first consideration would be related to the networking function. This is a key element that cannot be ignored.

For there to be a network operation, the connection between the elements that make up the system is essential. In an urban situation, these connectors may consist of green roofs or walls, permeable strips or even urban tree rows. In many cases, these are unusual connectors that should have been progressively replaced by more ecological ones, allowing genetic exchange and increasing entirety resilience. The connection of the urban elements should be extended to the peri-urban ones, which would serve as an intermediate system for the more natural ones. It can already be understood that all natural and semi-natural areas should be connected to each other, although the corridors would be different depending on the situation. In the urban corridors, the possibility of genetic exchange would be almost as important as the fact that they would serve for the city residents' traffic. For example, with the aim of being able to do sport or location access, they would be, in most cases, mingled corridors. A different case would be the green roofs and walls, in which this would be an impossible role. In peri-urban areas, the connectors could already (in most cases) be assimilated to ecological connectors or have an important part of their function focused on ecology.

Something similar would happen regarding ecosystem services. In urban areas, there should be a trend to maintain or restore those related to health and culture. From this point of view, landscape and health assessment tools would probably become the most widely used. In peri-urban areas, tools and methodologies related to landscape and Green Infrastructure would work synchronously. Finally, in purely natural (or slightly anthropized) areas, i.e. rural areas, ecological tools would be a priority, although landscape tools would also have their role dependent on those. In this way, the relationship between Green Infrastructure and landscape would probably be less conflicting as the needs of each area would be addressed.

Furthermore, it is critical to understanding the contrast or variation in each place, as this allows planners to address issues of scale more directly. The scale is determined by both spatial dimensions, and by the spatial or land planning instruments to be used. In fact, different scales are used, both in the analysis and in the intervention procedures, according to the different political or governmental levels (international, national, autonomous community and municipality). However, these relationships are not always direct and must show a certain degree of flexibility, as they vary from one country to another and even between autonomous communities or municipalities.

For this reason, landscape and Green Infrastructure studies can be carried out on a wide number of scales, which are also closely related to other aspects, such as their geographical expansion and location: from international, national, regional and county to the local scale. Preferably, the different scales used should fit together, in a correlated and hierarchical way, where each level offers the system features which are relevant to each one of them. This was discussed by Riesco et al. (2008, 229) who noted that:

> The adoption of these referential scales is not a simple convention for classifying what is observed, since, for both the territory and the landscape, it facilitates the interaction between method and object of knowledge, so that, in each area, what is observed efficiently calls the analysis to develop the appropriate sensitivity for the evidence that it can provide.

The competence for the transfer of considerations from one scale to another enriches enormously the understanding of the landscape and the territory. Both, the methodological background of the study and intervention in Landscape and in Green Infrastructure are approached differently depending on the observation scale and even the degree of mobility of the observer. From an ecological point of view, heterogeneity, and the relationships between spatial patterns and processes can fluctuate according to scale. This supports the Theory of Hierarchies which:

> considers ecological systems as complex systems, that is, it postulates the existence of a relationship between the entity (the object of study in question) and its context (the interrelations with its matrix), so that each hierarchical level has a different set of relationships. (Galicia & Zarco, 2002, 36)

Working at an international, national or even regional level, the scales are generally small (1:250,000), causing generalisation, simplification and reduction of detail, both in thematic and geometric aspects. The objective is usually to identify patterns related to landscape variation, in other words, landscape classification of wide dimensions. These patterns are overlaid on contributions related to large ecological structures and natural factors, to which are added cultural and historical aspects associated with the territory. At these scales, development, changes and trends demand in land management are often very clearly observed. Appreciations of a subjective nature, typical of landscape studies, such as landscape interpretation and sensorial perception, can be difficult to integrate though.

At a county or sub-regional level, the scale increases, 1:50,000 and 1:25,000 being the most common (although some studies use more detailed charting, at 1:10,000 and 1:5000). On the one hand, the definition of territory is related to physiographic aspects, such as geomorphology, vegetation cover, hydrology, climate, fauna, soils, etc., which are in concert with ecological approaches, more typical of Green Infrastructure. On the other hand, it is related to the visual and scenic structure of the territory, with the historical and cultural processes and the socioeconomic activities developed (historical evolution, type of settlements, land use and cover, territorial dynamics, etc.), which are more in line with and related to Landscape studies. It is a scale which goes beyond the municipal sphere, in administrative terms, and, therefore, is widely used in planning policies and management and territorial planning, in addition to other sectorial areas, such as the environment, heritage, and agriculture, where Green Infrastructure and landscape can be considered for all of them in a transversal way, i.e. 'the regional scale is relevant as a geographical sphere of "a landscape with sense" and as a territory for landscape planning' (Mata & Fernández, 2003, 15).

The local scale has the highest level of detail and can diverge depending on the size of the area under analysis (1:2500 to 1:200). It is a scale which, on landscape and Green Infrastructure terms, can be quite conditioned by urban and urbanisation processes. A detailed description of the situations and elements that make up the character of the place is made on it. Given the daily and direct relationship that the analysed areas at these scales usually deal with populations, and their importance in quality of life, health, and well-being, it may therefore be easier to include aspects related to subjective perception in such discussions. It is at this scale, where the weight of landscape tools predominates over those with a more ecological nature (although they should also be considered). These scales, because of the dimensions of the studied spaces, are frequently used in municipal areas, through municipal urban planning and development planning, for example.

3.5 Critical Relationship Between Green Infrastructure and Landscape Structure

Currently, discussions are not only focussed on different professional competences but also in determining the objectives and instruments used by these professionals. From the discussion outlined above, the indicated path is probably a complementary one. On both sides, steps have been taken to align landscape ecology principles that accentuate objectives and instruments which are remarkably close to those of Green Infrastructure. Thus, the connected system approach, i.e. networks and corridors, are supportive of this assessment. Moreover, a consideration is needed for framing landscape as a set of cultural services by and within the Green Infrastructure practice, by introducing the subject as a spectator in the case of the landscape and as an element to be considered in case of identity- and sense-of-place-related questions. This leads us to think about the steps that are being taken in the direction of complementary tools and purposes.

In a landscape, there would be an object, but also a subject which is the main entity, as there is a strong subjective component. In contrast, within Green Infrastructure, the main focus is the object, the compendium of relations and elements in a territory. However, as an ecosystem service, landscape is also important, but in this case, the subjective element is clearly subordinate to the objective values. Therefore, this means that, even though we may want to study the landscape only, we cannot avoid studying the object as well. And, even though what we study is a Green Infrastructure, there is no such thing as Landscape as part of the Cultural Services provided by that infrastructure. But priorities, objectives and tools could be different or, at least, complementary. That is precisely what would differentiate tools and approaches.

It has also been understood that, paying special attention to the location and the scale, although less to the latter, the predominant concept can vary. Although the above discussion has focused on three specific areas (the city, peri-urban areas and natural or rural areas), many other specific situations can take place. It is therefore necessary to carry out a specific study of each case (i.e. studies more focused on the ecological component of Green Infrastructure or on the cultural component, associated with landscape). Finally, we want to highlight that both approaches are necessary even if, depending on the case, one will be more important than the other.

Thus, in urban or more anthropized areas, landscape objectives and, consequently, their methods and tools should be considered as a priority. This does not mean that there should not be a Green Infrastructure in urban areas though. On the contrary, its existence is essential, since without the ecological base and the exchange with other areas, a specific landscape could not be maintained, if, of course, there are natural or semi-natural elements in it, as indicated above. The opposite case is less frequent, but there is a need to consider the lack of ecological resources in anthropized areas. At this point, ecological concerns will be critical. But again, landscape elements should not be ruled out, especially in areas such as parks, where their use for enjoyment by the population is important. Finally, in those zones which could be described as peri-urban, a specific study of each case would have to be made to see the priority objectives to be achieved.

As a conclusion, it could be stated that 'location' should be introduced as a new element, in both cases, when considering a Green Infrastructure or a landscape, and at a lesser level the scale, which should always be conditioned by the location. Then, an urban Green Infrastructure presents diverse features respecting a non-urban Green Infrastructure, which means prioritising some ecosystem services in case of divergence, without disregarding ecological considerations, which would be at the base of any proposal.

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Chapter 4
An Evolving Paradigm of Green Infrastructure: Guided by Water

Paulo Renato Mesquita Pellegrino and Jack Ahern

Abstract Green infrastructure (GI) is a strategy to support sustainability, resilience, and climate mitigation/adaptation in the built environment. GI has been in use for several decades although under a variety of names, and continues to evolve a more holistic and multifunctional focus to address all four categories of ecosystem services (provisioning, regulating, supporting, and cultural). To address ecosystem services, GI can be practiced to guide urban form, spatial structure, and aesthetics – guided by the movement of urban water in cities. To support sustainability and resilience goals, GI requires a transdisciplinary process including the co-production of knowledge and a robust culture of evidence-based decision-making based on GI performance monitoring. A culture of learning-by-doing is emerging that conceives urban design and planning as experiments – capable of addressing the "moving target" of climate change in cities. These design experiments require that performance monitoring is consistent and robust – and that the findings are subsequently applied to decision-making in an adaptive mode. An application of the theories and practices associated with GI in the Sao Paulo, Brazil watershed of Jaguaré is presented as an example of the current state of practice – and identifies questions and research needs for future applications.

Keywords Urban hydrology · Design experiments · Paradigms of urban water management · Nature-based solutions · Urban climate adaptation

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4.1 Introduction

The world is now two decades into the “Century of the City” (Pierce and Johnson, 2008). When the world’s population became predominantly urban in the early twenty-first century, it became clear to policy makers and urban planners that the challenge for sustainability and resilience must be addressed in cities (U.N. 2007). An international consensus is emerging that green infrastructure as a nature-based solution is a preferred strategy/model to support urban sustainability and resilience and to mitigate and adapt to climate change (Bacchin 2015; U.S. EPA 2015; Barthelmeh and Mcwilliam 2014; EC 2013; EPA 2020; Hoang and Fenner 2016; Silva 2020).

Green infrastructure has multiple definitions including a foundational one by Benedict and McMahon(2006)) as “an interconnected network of protected land and water that supports native species, maintains natural ecological processes, sustains air and water resources and contributes to the health and quality of life for communities and people.” This definition describes a broad−/regional-scale network of protected landscapes to deliver ecosystem services. Benedict and McMahon’s definition is notably non-urban and bears less relevance to the urban built environment. A more recent definition of GI in Section 502 of the US Clean Water Act defines green infrastructure with a water-resource-focus as “...the range of measures that use plant or soil systems, permeable pavement or other permeable surfaces or substrates, stormwater harvest and reuse, or landscaping to store, infiltrate, or Evapotranspiration (ET) stormwater and reduce flows to sewer systems or to surface waters” (EPA 2020). Ahern proposed an urban-oriented definition of GI as “Spatially and functionally integrated systems and networks of protected landscapes supported with protected, artificial and hybrid infrastructures of built landscapes that provide multiple, complementary ecosystem and landscape functions to a broad public, in support of sustainability” (Ahern 2011). Green infrastructure has been discussed and defined in numerous publications with global application. Mell (2016) provides a more complete discussion and comparison of these GI definitions, goals, and policy contexts, including their evolution and contemporary trends.

Green infrastructure guided by water can be understood as an adaptive system – a complex, open entity that adapts to changing circumstances and disturbances and works with the dynamics and pulses of small and large urban landscapes. In contrast with established ideas about urbanism that assumed coherence, stability, and permanence of the structures and urban form, an adaptive framework fits better for urban landscapes that are defined by mobility, change, disruption, and growth (Baccchin 2015; Corner 2006). As an adaptive system, green infrastructure is involved in the emerging challenge for resilience (ARUP 2014; Rockefeller 2015).

With this history and evolution in mind, and to address contemporary and future challenges to achieve sustainability and resilience, we propose that urban green infrastructure have the following six characteristics: guided by water, climate-engaged, multifunctional, nature-based and hybrid, adaptive, and transdisciplinary and equitable. Each of these characteristics are discussed further below.

4.2 Guided by Water

We assert that hydrology is the principal function and guiding process for urban green infrastructure. It is a provider of multiple ecosystem services and is therefore fundamental to urban sustainability and resilience. Water is one of the best indicators of natural processes because it is a transboundary element that integrates different environmental and sociocultural values and processes and is integral to decision-making in most urban areas.

Urban GI offers a promising alternative to conventionally engineered "gray" infrastructure (Dunnett and Clayton 2007; Girling and Kellett 2005). The idea of infrastructural functions embedded into the landscape is not new, but nowadays we are arriving to the realization that infrastructure projects must align sanitation engineering, landscape architecture, urbanism, and ecology to support urban sustainability and resilience (Nijhuis et al. 2015; Shannon and Smeets 2010). We can no more ignore the dynamic natural and social backgrounds that feed their transformation and how new infrastructures should take advantage of these processes and help integrate the built environment to nature and to social needs. This focus could internalize principles of adaptation, resilience, and sustainability to address environmental and social changes that pose threats and challenges to meeting sustainability and resilience goals.

Green infrastructure has evolved concurrently with twenty-first-century policies to address sustainability and resilience. A central theme in this evolution has been a focus on water as a key/integrating physical and ecological resource, as a key and specific mechanism of urban flooding and urban climate change adaptation, and as an indicator of sustainability and resilience. Water is thus the appropriate basis for the spatial and functional organization of a new type of "green" urban infrastructure (Silva 2020; Bacchin 2015; Rottle and Yocum 2010; Paul and Meyer 2001).

Water is essential for all forms of life – 60% of the human body and 70% of the earth's surface is comprised of water. The movement of water over geological time is responsible for the erosional processes that form and transform topography and landscapes. More than any other resource, water integrates humans with their environment. As the universal solvent, as water moves across and through cities, it responds continuously, in real time, to the built environment and transports virtually everything it contacts to downstream or subsurface locations (Leopold, 1997).

The physical and chemical properties of water are fundamental to climate and climate change. The molecular structure of water causes large amounts of energy to be absorbed or released during its phase transitions (freezing, evaporating). During freezing, energy is released into the atmosphere, and during evaporation energy is absorbed as latent heat in water vapor. And when water vapor condenses as precipitation, the latent heat is released. These energy transformations are the principal mechanisms for the global transfer and balance of heat and the driver of global and local weather patterns. Water is therefore a principal mechanism by which climate change occurs. At the global scale, water management is somewhat beyond human control. At the scale of the city or the neighborhood, however, water is quite manageable with appropriate green infrastructure. Urban water can be managed with green infrastructure to influence local microclimate conditions which directly influence human comfort and health. For example, by planting street trees, evaporative cooling can be managed to reduce the urban heat island effect and effectively cool the local air (McPherson 1994). Or planted green roofs intercept and evaporate precipitation cooling the buildings beneath them. Water is therefore a key to managing and adapting to a changing urban climate.

Novotny (2010) provides a useful history of urban water management that has evolved historically through four paradigms (Table 4.1). The current (4th) paradigm started in 1972 with the passage of the US Clean Water Act that directly resulted in an emphasis on gray infrastructure to provide engineered, end-of-pipe treatment to address water pollution. This paradigm, started in the USA, has influenced water policy worldwide and made major improvements to water quality in the twentieth century. However, Novotny notes multiple limitations of this fourth paradigm: not effective for managing non-point source pollution, includes no concepts for water re-use, no capture of energy or nutrients in wastewater, fails to address the impacts of treated effluent on receiving waters, and it doesn't address carbon emissions or the impacts of climate change on urban water resources. In agreement with the International Water Association.

Novotny (2010) argues for a fifth paradigm for urban water management that replaces the linear, flow-through fourth paradigm with a closed-loop "green infrastructure" paradigm promoting water conservation, water and energy reclamation, and reuse within a "total urban hydrologic cycle." The fifth paradigm integrates surface and subsurface water flows, stores and conveys water for re-use, provides water for flow-deprived rivers, and treats polluted water flows. It supports sustainability goals in an integrated and holistic manner and with substantial political

Table 4.1 Paradigms of Western urban water management

Paradigm/ parameter	1. Ancient	2. Roman age	3. Industrial period	4. U.S. clean water act	5. Sustainable water management
Time period	B.C. to middle ages	Ca 300 B.C. To nineteenth century	19th–twentieth century	1972>	Twenty-first century >
Water supply	Local wells	Local wells + distribution system	Major distribution system	Large-scale water treatment	Central systems + water capture and re-use
Wastewater	Street + informal	Street + Engineered	Combined sewers	Combined sewers	Separated sewers + non-point source management
Stormwater	Limited to street drainage	Street + engineered drainage	Combined sewers	Combined sewers	Non-point source management + green infrastructure
Functions	Primitive conveyance	Engineered conveyance	Advanced conveyance	Point source treatment	Multifunctional + nature-based solutions

Novotny (2010)

cooperation. Green infrastructure is the suite of applied practices that can be applied to realize the fifth paradigm of urban water management.

A number of existing frameworks emphasize the potential role of water in cities to support sustainability and resilience: low-impact development, sustainable urban drainage systems, Integrated Water Resource Management, Integrated Urban Water Management, Water-Sensitive Urban Design, and Water Sensitive Cities (University of Arkansas Design Center 2010). These frameworks share three common "pillars": community and networks, urban water catchments, and providers of ecosystem services (Özerol et al. 2020).

Drainage catchments, including urban sewer and watersheds, have been formed, over geological time by the capacity of water to erode and transport materials downslope creating topographic form. The resulting topographic and engineered structure and form of urban water catchments determines the gravity-based flows of urban hydrology and therefore should be consulted as a water-generative approach to design spatial concepts for urban GI planning, design, and management (Leopold 1997).

4.3 Climate Engaged

GI originated largely to address stormwater management and urban flooding. In the USA, although the focus of GI delivery varies in other locations, GI addresses urban flooding with a combination of decentralized source controls (i.e., street trees, porous paving, greenroofs), conveyance and infiltration practices (rain gardens and bioswales), and stormwater storage and treatment in created wetlands.

As twenty-first-century cities struggle to meet the challenges imposed by climate change, urban green infrastructure can play numerous roles. GI, by definition, employs natural functions and processes which include macro- and micro-climatic dynamics. GI has the inherent capacity to mitigate, adapt to, and manage both the causes (mitigation) and impacts (adaptation) of climate change. GI supports urban livability, non-motorized transportation, and renewable energy generation and use – important strategies/goals for mitigation of greenhouse gas generation, the primary cause of climate change. GI has already proven effective in adapting to specific impacts of climate change including urban heat island effect, increased/reduced precipitation, urban flooding, and sea level rise (Plastrik and Cleveland 2018). While climate engagement has not always been noted as a primary function of green infrastructure to date, it surely will be in the future (Hoyle and Gomes Sant'Anna 2020; Mell 2016; Matthews et al. 2015).

4.4 Multifunctional

In urban environments space is limited by definition. The fourth-generation infrastructure of the twentieth century is manifest in the modern paradigms of industrialization, specialization, and efficiency. This paradigm, in part, has led to a global crisis of sustainability and has failed to address the causes and consequences of climate change. The new (5th) paradigm of urban green infrastructure is inherently multifunctional – combining functions within common spaces, achieving spatial efficiency to provide a broad suite of ecosystem services. The idea of embedding infrastructural functions within the landscape is not new. To be effective, urban GI must integrate sanitary engineering, landscape architecture, urbanism, and ecology to support the renewal and resilience of cities and regions. New concepts for "floodable" urban spaces and parks provide storage and treatment for excess stormwater when needed, but also provide additional, valued ecosystem services including nature protection, wildlife habitat, food production, and spaces for social gathering recreation. (LaLoggia et al. 2020; Sijmonds et al. 2017).

Because urban spaces are socio-ecological resources, multifunctionality is supported by diverse public constituencies to be sustainable over the long term. When GI is planned and designed with diverse stakeholder involvement, it can provide the ecosystem services desired by diverse constituencies and thus benefit from their support. And when the performance of the GI is rigorously monitored, it will generate viable scientific data that will raise awareness of GI and lend it support into the future (Pellegrino et al. 2014).

Renaturing of cities is a part of a multifunctional strategy "to maximize the ecosystem service provision of urban green infrastructure (UGI)", combining habitat services and a biodiversity-led approach with multifunctionality addressing community needs and policy learning. Connop et al. (2018) add the important point that rather than assuming that GI has generic benefits, planning requires close attention to the local context for both green and multifunctionality objectives, including but not limited to enhancing biodiversity, reducing heat stress, carbon sequestration, reduction of air pollution, water management, and human health and well-being.

4.5 Nature-Based and Hybrid

Nature-based solutions can be considered to be an umbrella concept covering a range of ecosystem-based approaches, including green infrastructure, that address specific and multiple societal challenges while simultaneously providing human well-being and biodiversity benefits (Cohen-Shacham et al. 2019; Kabish et al. 2017; EEA 2015).

Urban green infrastructure combines conventional, gray, engineered infrastructure with nature-based solutions in novel ways. The unifying and guiding concepts are sustainability and resilience. Due to density and competition for space, existing urban environments often have spatial limitations to apply purely nature-based solutions. This is where hybrid infrastructures are needed to support green infrastructure – combining nature-based with engineered solutions. For example, to manage stormwater in hyper-urban environments, pervious paving and underground water storage cisterns can be combined with nature-based surface infrastructures including rain gardens and bioswales (Rouse and Bunster-Ossa 2013; Rottle and Yocum 2010; San Francisco Public Utilities Commission 2009). Our definition of urban green infrastructure explicitly includes these novel hybrids of nature-based and engineered infrastructures.

4.6 Adaptive

Green infrastructure needs to adapt to changing base conditions and varying contexts. GI needs to be adaptive, monitoring the performance of interventions and revising best practices and standard procedures continuously (LAF 2020; Ahern 2010). Increasingly, contemporary practice builds on earlier initiatives like low-impact development and recent innovations including the spread of best management practices to address specific landscape types, strategies, and cases for green infrastructure in the city.

As the term green infrastructure has become mainstream, the fourth-generation paradigm in efficiency and control based on a civil engineering approach to infrastructure have been replaced with adaptive concepts that deal with the ideas of bringing diversity and complexity as parameters for planning and design. For this adaptation to succeed, a profound change in professional culture is needed. Professional practice has been reluctant to accept and practice monitoring of post-construction project performance (Ahern 2011). An adaptive approach to the monitoring of green infrastructure performance is needed in terms of delivering specific ecosystem services. Performance monitoring holds great potential to generate new knowledge and best practices. New models are emerging to promote monitoring and adaptation, for example, the "Landscape Performance Series" by the Landscape Architecture Foundation (LAF, 2020). An emerging culture of monitoring is already providing place-specific data to adapt planning and design practices to support specific ecosystem services.

4.7 Transdisciplinary and Equitable

In meeting the challenges of sustainability and resilience, urban green infrastructure directly serves the needs of society. To be equitable and sustainable, the processes of designing, constructing, and managing GI need to be transdisciplinary based on knowledge, participation, and support of all stakeholders and decision-makers.

Under an interdisciplinary approach, experts, stakeholders, and decision-makers operate independently until the point of consultation and decision – near the end of a project. Under a transdisciplinary approach, diverse participation is fundamental – through all stages of planning and implementation (Tress et al. 2003). This manner of transdisciplinary planning and design recognizes and applies local knowledge and is inherently equitable and supportive of the core sustainability value of social equity.

By articulating functions that are critical, e.g., sanitation, flood protection, decontamination, restoring biodiversity, energy production, access to food, and transportation – as landscapes that are part of everyday life – green infrastructure that is guided by water aims to help create a more flexible, open, and equitable city and region, one that is fit for the environmental, economic, and social challenges of our times.

4.8 Summary of Urban Green Infrastructure Principles

Urban green infrastructure has already been proven as an effective strategy and set of best practices for cities to provide ecosystem services in a context of global urbanization and climate change. A new green infrastructure, guided by water, embraces multiple objectives including enhancing biodiversity and the social life of urban parks and plazas. This approach replaces mono-functional spaces that were often functional only a few days a year and generally void of public use.

The theory and practice behind urban green infrastructure is in a continuous state of evolution in response to the rapid dynamics of global urbanization and climate change. The six principles articulated above are intended to both describe the recent evolution and guide the future of urban green infrastructure to meet the profound challenges to realizing urban sustainability and resilience.

This chapter points to these possibilities and advances recent work on landscape urbanism and landscape infrastructure by offering specific working concepts, methodologies, and landscape types for a new green infrastructure – guided by water.

To examine the benefits of using GI practice that is guided by water, the following is a discussion and summary of the Jaguaré urban watershed plan in São Paulo, Brazil. This plan is presented here to illustrate and discuss the application of the six characteristics of urban green infrastructure presented above. This plan is an academic study from the University of São Paulo prepared under the direction of Professor Paulo Pellegrino (FCTH 2017) (Fig. 4.1).

Fig. 4.1 A comprehensive green infrastructure plan for the Jaguaré basin FCTH (2017)

4.9 The Jaguaré Urban Watershed Plan: A New Generation of Urban Green Infrastructure – Guided by Water (Fig. 4.2)

The Jaguaré Creek plan was designed to be replicated in the other basins of the Metropolitan Region of São Paulo. The project was managed by the Águas Claras Association, coordinated by the Fundação Centro Tecnológico de Hidráulica (FCTH) and financed by the São Paulo State Water Resources Fund (FEHIDRO). An interdisciplinary team was assembled including engineers, landscape architects, and urban planners to deliver the project. The project process was a non-linear one studying and then proposing a new Green Infrastructure plan in an iterative manner. The project's focus was to reimagine and redesign an existing massive stormwater basin, locally known as piscinões, to meet present and expected future stormwater conditions while also providing additional functions and ecosystem services. The Jaguaré Basin represents 1/10 of the area of the larger Pinheiros River Basin, with an area of 27 km2, and is located within the western sector of the city of São Paulo (Fig. 4.3). The basin is characterized by diverse urban land uses, representative and

Fig. 4.2 The vision of the Jaguaré Urban Watershed plan and pilot project for Urban Basin Revitalization, where water, land, and buildings and the existing gray infrastructure are integrated FCTH (2017)

typical of other hydrographic basins in the metropolitan region of São Paulo (FCTH 2017).

São Paulo is a city of rivers and hills. Currently, water in the city exists as a paradox of excess and scarcity – drinking water supplies are critically low even as devastating localized flooding occurs regularly across the city. São Paulo is an extreme case of the common challenges for urban water management. The problems and potentials of living with water in this dense urban environment are explored thoroughly in this project.

São Paulo can be traced back hundreds of years and is fundamental to the city's culture. The project thesis is that *piscinões* – existing large and expensive detention ponds designed for flood protection – must be constructed as multifunctional civic landscapes, that is, designed places that provide multiple ecosystem services and thereby enrich the biophysical fabric and social life of the city. New design frameworks and propositions were considered that explore the social and ecological potentials of *piscinões* to be designed as civic infrastructures and offers a technical and conceptual approach for rethinking these projects in terms of resiliency, environmental recovering, and cultural agency (Fig. 4.4).

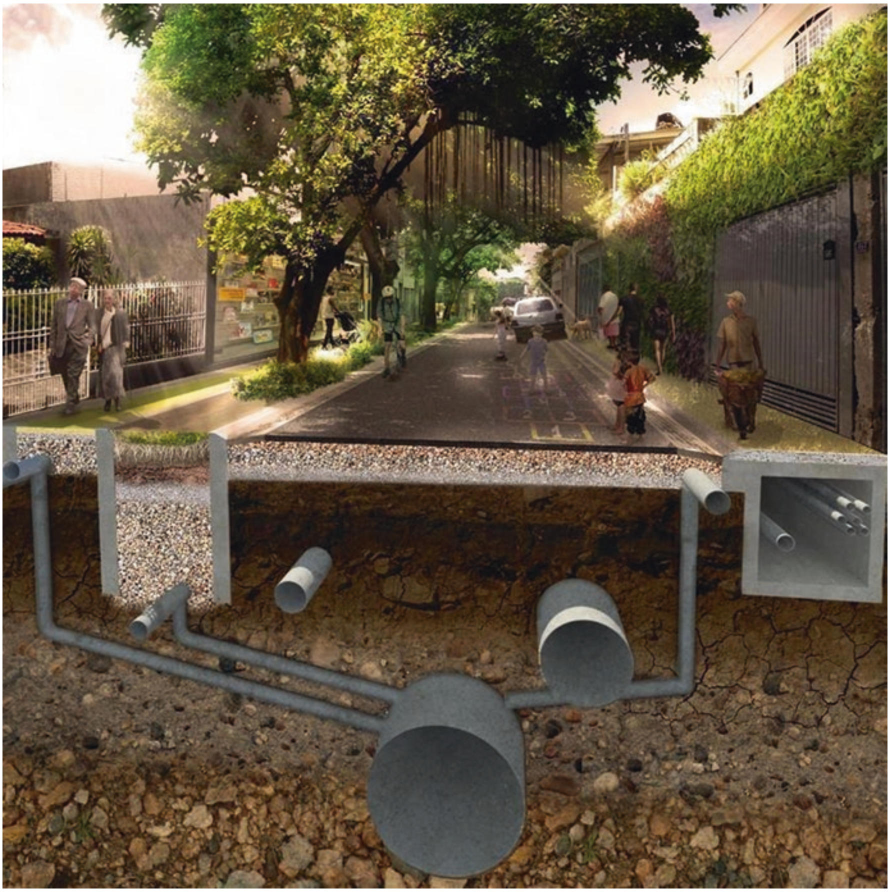

Fig. 4.3 The Jaguaré plan carefully fits urban green infrastructure into an existing, dense neighborhood with narrow streets to meet the challenge of extreme climatic events FCTH (2017)

4.10 Guided by Water

The main research question that guided the project was to reframe the city and neighborhood's relationships with water – looking at how the flux of water can be guided by both actions to regenerate the Jaguaré stream and protect and enhance other uses for the city. The project expanded this original research question, defaulting to more conventional ideas about stormwater management and best management practices (BMPs). While these BMP's are also needed, they are not the primary objective here. Therefore, the project re-conceptualized its approach in the following ways.

First, examining the places where the urban, ecological, and hydrological characteristics of the places where headwater springs initially appear. In this adaptive design research, the project explored what is possible, why it matters, and what the

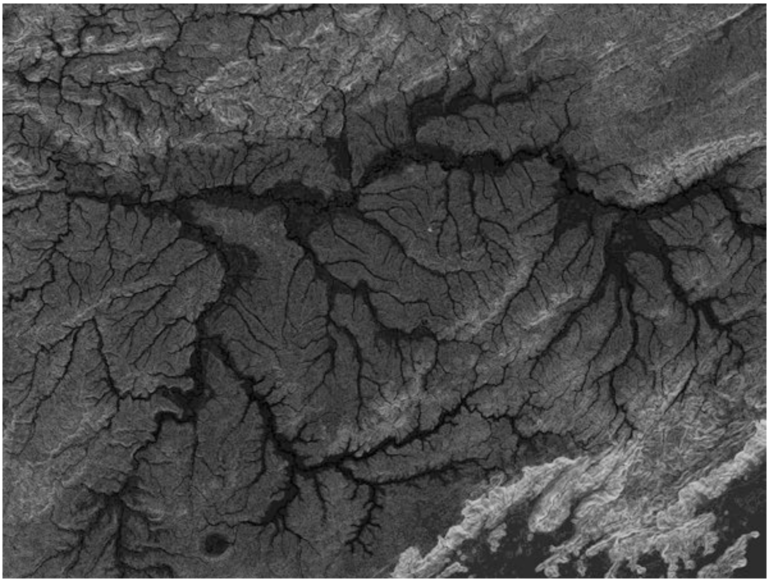

Fig. 4.4 The urban agglomeration of São Paulo occupies a sedimentary basin characterized by hills and alluvial plains, a large tangle of rivers, and streams leading to a single drainage channel (FCTH 2017)

implications of design decisions are – not only to solve all the problems or provide concrete answers. It was an iterative process of exploration, evaluation, and revision. While the collection of stormwater is a very interesting part of this project (due to the fact that so much of the city has been paved and thus groundwater has been converted to surface flow), it is not the most important. The most important form of the water in the City is still the "springs" where the water first appears, becoming the focal point of the proposed Green Infrastructure. The springs typically follow a change in the topography, or, in other cases, occur where the channels and pipes openly discharge stormwater into the catchment basins. These ideas for approaching regeneration and the presence of water are part of the project's design thesis, exploring possibilities and visually demonstrating their potential effects. While the project included some analysis drawings and writing, the majority of the work was rigorous, precise speculative drawings exploring the visible design effects (Fig. 4.5).

Second, the speculative design drawings make a strong case for how these new GI spaces function through the seasons. The unique, seasonal monsoonal hydrological regime of Sao Paulo is different from other cities where urban water strategies have been developed. The design must reflect and respond to this reality, specifically by showing how the landscape would appear and function during both rainy and dry seasons, and during major storm events and droughts.

Finally, it is a demonstration of the multifunctional aspect of the landscape (hydrological, ecological, urban). For each of these, the project quantified the effects when possible (how much water would be retained, how many months of the year

Fig. 4.5 The channels of the creeks can be revitalized by including additional proposed vegetation and re-designing the stream's land forms to manage current and future stormwater FCTH (2017)

the GI would be expected to have running water). At this stage most of the project was speculative, from a team of PhDs and professional practitioners working collaboratively. The alternatives generated show a range of possibilities to support an informed and ongoing discussion with stakeholders.

4.11 Climate Engaged

This project included strategies and proposals for both mitigation and adaptation to climate change. To address the causes of climate change (mitigation), the project explored how to reduce CO_2 emissions, protect, and enhance the forests, vegetation, and soil that store carbon. The project also includes landscapes that provide local access to recreation and social interactions, avoiding the need to travel for recreation and thus reducing the carbon footprint of the population. The project is deeply engaged with adaptation actions and strategies with urban green infrastructure and nature-based solutions. Adaptations include increased vegetation to mitigate the urban heat island effect and preparing for even greater precipitation and flooding events in the future.

4.12 Multifunctional

The Jaguaré watershed plan illustrates the potential of multifunctional green infrastructure. The project employs a new generation of flooding infrastructure to reduce flood risk, provide public space, and improve water quality in cities. The project was completed through the applied research group LabVerde at the University of Sao

Paulo in collaboration with FCTH and others. In Sao Paulo, as in Brazil in general, there are significant challenges to making the piscinões function as multifunctional landscapes. It requires specific professional expertise to understand the design requirements and compatibilities of the multiple functions that were considered.

The Jaguaré project shows the potential to learn lessons and new techniques for understanding the dynamics of the intense social river landscapes that could have tremendous impact on the design and management of flooding infrastructure and public space. There is also an opportunity to support a new research network working on the multifunctional challenge from different disciplinary perspectives and in different geographic locations, aiming for a synthesis and integration of human and natural processes. This research network holds great promise to understand how to live with water in cities. Form and function of rivers and cities here is explored as and multi-scalar, interrelated complex within the socio-environmental system (Fig. 4.6).

4.13 Nature-Based and Hybrid

Based on the study of existing low-impact drainage devices (LID), the project recommended structural measures for micro and macro drainage. The distribution of nature-based LIDs in the hydrographic basin, as elements of decentralized control of runoff, detains small volumes of water and, above all, removes part of the non-point source pollutant loads carried by the first rains (first flush).

Fig. 4.6 A parametric process of design can give new dimensions to the detention ponds, as here where the green infrastructure overlays many functions FCTH (2017)

The project's bio-retention hydrological features include both nature-based and hybrid solutions to provide the necessary stormwater management. Large LIDs, such as detention and retention basins, occupied residual open spaces, areas along streams, and areas to be expropriated in order to absorb and store the expected water volumes for rains of intensity up to 100-year storms.

During the development of the research, there was a need to address the issue of solid waste, identified as one of the major problems regarding the functioning of traditional or green. The Watershed Revitalization Proposal includes a variety of actions to achieve the goal to get a better river, including sanitary, garbage collections, water reservation, and detention and an integrated bmp network through the contribution area drainage infrastructures, as well as domestic and industrial wastewater, currently the primary contributor of water contamination in the basin. Thus, four specific objectives of the Project are identified:

– Cushion the impact of rainwater of intensity TR 100 years.
– Propose non-structural actions for the management of solid waste in the basin.
– Remove the largest possible volumes of diffuse pollution.
– Reduce biological oxygen demand (BOD) in streams to stipulated levels by Class 3, waters that are then suitable for (a) supply for human consumption, after conventional or advanced treatment; (b) irrigation of trees, cereal, and forage crops; (c) amateur fishing; (d) recreation of secondary contact; and (e) animal feed; as provided by the local resolutions.

4.14 Adaptive

The project procedures involved field measurements, laboratory analysis (water quality), simulations, and modeling in the PCSWMM hydraulic models, georeferenced data in ArcMap-GIS and simulations of drawings in AutoCAD (use of land, drawing of technologies, and simulation of the occupation of Open Spaces by LIDs), and parametric models Grasshopper (new generation of reservoirs). All these procedures were incorporated into a non-linear work process that maintained a holistic view of urban drainage throughout the project. Collectively, these procedures supported an adaptive design process that continuously responded to the findings of field-based measurements and computer models of performance. This adaptive design process supported the development of three exploratory scenarios: *Critical Scenario*, *Governmental Planning Scenario*, and *Revitalization Scenario*. The Critical Scenario considered that none of the government plans would be implemented and that there would be no future plans related to water management in the basin. The Environmental Planning Scenario considered that all existing Government Plans and Actions would be implemented. The Revitalization Scenario, on the other hand, considered that in addition to the implementation of existing plans and actions, the demands analyzed by the Jaguaré Project from the structural and non-structural measures of Green Infrastructure (blue) proposed in an action horizon until the year

2040 would be met. These scenarios were part of an iterative, adaptive process, and identified water quantity and quality parameters recommended to be monitored in the future.

4.15 Transdisciplinary and Equitable

To communicate the key ideas and recommendations of the Jaguaré project, we developed the project slogan: *Intelligent Landscapes*, which sums up the three main strategies of the Jaguaré Project: bioretention (intelligent streets = intelligent people, waste collection, permeability/imperviousness, etc.); *interception and treatment of illegal pollution* (intelligent sanitation = intelligent dwelling, urban economy, and favela urbanization). To provide equitable and sanitary wastewater treatment, we proposed compact sewage treatment plants for the favelas (informal developments) and finally *flood risk management* (intelligent reservoirs = intelligent public policies, public investments, leisure, water friction, etc.). This project slogan was intended as the outline to attract, and engage, local stakeholders and decision-makers in a transdisciplinary planning and design process. The ultimate goal was to achieve a solution that was fair and equitable for all involved.

In summary, Project Jaguaré demonstrates the application of the six guidelines for urban green infrastructure – guided by water. As with any project that attempts to challenge the status quo, questions remain at the conclusion of the project:

- What are the key areas of uncertainty regarding the design of urban green infrastructure for water and hydrology? In a context of climate change, one cannot use historical precipitation and flood data. Data for future conclusions is both essential and also highly uncertain.
- What are the specific urban green infrastructure ecosystem services provided to be monitored? Can "universal" ecosystem services be considered to provide a "lingua franca" (common language) that could encourage knowledge sharing and advancement?
- Or should they be adapted to local conditions? Likewise for monitoring protocols for measuring the performance of GI to provide these services? Can common/accepted protocols be designed and accepted?
- How can a transdisciplinary and equitable approach be organized and managed – given the uniqueness of each cities' demographics, government, culture, economics, and policies?
- How to enhance not only ecological values but also public health and quality of life for citizens and support a green economy with new job opportunities? Responding to the need to develop a systemic approach that combines technical, business, finance, governance, regulatory, and social innovation?

4.16 Conclusion

This chapter proposes and applies an approach to urban green infrastructure – guided by water. Urban green infrastructure is evolving towards a fifth paradigm model of sustainable and resilient urban water management. This model can be described with six characteristics: guided by water, climate engaged, multifunctional, nature-based and hybrid, adaptive, and transdisciplinary/equitable. The Jaguaré project clearly demonstrates and illustrates how urban green infrastructure can be guided by water, following the six characteristics proposed. The Jaguaré project offers several important lessons for using the approach elsewhere:

- Allow the regenerative capability of nature, the time, and space it needs to function. Using nature-based solutions as the priority for regeneration.
- Cultivate messy ecosystems – understand and respect the cultural need to show intentionality and care while also promoting nature-based solutions. Green infrastructure needs a new aesthetic founded on ecological functions, but also responsive to cultural values and norms.
- Don't underestimate the value of a comprehensive accounting/monitoring of project costs and benefits. The economic data that monitoring can provide is perhaps the best possible support for the idea and reality of multifunctional landscapes.
- In the project accounting, include the costs and consequences of current impacts of water quality on environmental and public health.
- Expand the concept of nature-based solutions to "landscape based" solutions – including the geographical, social, and economic context of proposed solutions.
- Pay attention to the water that runs in your street. Realize that it is part of an urban watershed with the potential to mitigate extreme precipitation events – providing local benefits as well as supporting downstream sustainability.
- Finally, urban green infrastructure guided by nature challenges society to rethink its relationship with nature and how the natural world is capable and prepared to reclaim damaged and polluted urban waters creating the possibility for sustainability and resilience.

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Chapter 5
Multifunctionality and Green Infrastructure Planning: Inter-City Biological Corridors in Costa Rica, as An Educational Methodological Strategy

Laura Chaveri-Flores and Guillermo Chaves-Hernández

Abstract The fragmentation problem that jeopardizes ecological connectivity has increased in Mesoamerica. However, some academic and institutional initiatives have embraced green infrastructure for contemporary urban development planning. Educational methodological strategies which are being used in the university environment, arising from the analysis of the concepts of green infrastructure and its multifunctionality, are presented here. The methodology consists of bibliographic and chronological research, analysis of design methods based on teaching experience, and research case studies. This work establishes a historical account of green infrastructure in Mesoamerica, a subject recently introduced in Costa Rica, as well as the presentation of replicable design tools in landscape planning. The corridors constitute new systems for the definition of green infrastructure, and they fulfill ecological, landscape, urban, and social protection functions. Multisystemic design, multifunctionality, and multiscale analyses and proposals constitute methodological tools that can be used in areas of social vulnerability, such as the Tirrases district. In conclusion, in university education and research, the contribution of new knowledge is essential to train highly aware professionals with an integral and multiscale vision, in synergy with biological corridors, protected area systems, and other cultural assets of heritage value.

Keywords Multifunctionality · GI · Costa Rica · Landscape · Educational methodological strategy

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5.1 Introduction

In recent years, the concepts of green (GI) and blue (BI) infrastructure have been an urban planning tool considered key to sustainability. They imply the strategic management of a network of vital spaces for the maintenance of a healthy ecological function, guaranteeing ecosystem services such as social welfare, biodiversity conservation, water, and food sovereignty. GI is understood as the interconnection of a natural life support system, linking wildlife habitats with other natural and conservation areas, such as greenways and parks (Benedict & McMahon, 2002, p. 5). It can be seen as a creative resource to promote strategies within public policy and community cooperation.

GI development should be conceived as an integral component, essential for building sustainable and well-designed communities. Growing societies need to improve both their gray infrastructure (roads, sewers, energy distribution) and their GI (Benedict & McMahon, 2002, p. 5). In Central America, employing GI would reduce the risk of weather events and catastrophes such as prolonged droughts, tropical storms, and occasional danger from volcanic eruptions. Climate change is exacerbating meteorological phenomena, as predicted in the Charney Report in 1979 (De Vengoechea, 2012, p. 6). From the design of the GI, it is possible to contribute significantly to precautionary and mitigation strategies. The questions raised regarding this issue are: how has the GI concept been received in the region generally and in Costa Rica (CR) specifically? And what actions have been carried out for its implementation?

This chapter explores some fundamental concepts related to GI, such as multifunctionality and GI planning. Elements of landscape ecology are introduced, such as corridors. Next, the environmental problems that the Central American region has undergone are studied, as well as the high profile that GI has acquired in CR, as a flexible tool adaptable to different contexts. In this way, it enables synergy between landscape systems, by being integrated as an analysis and diagnosis methodology that addresses multifunctionality as one of the pillars to respond to the most recurrent environmental problems. Additionally, the antecedents of GI and its link with the Interurban Biological Corridors (CBI) in CR are analyzed. Different initiatives that have been developed in the country are studied, such as the inclusion of the main universities in these programs. The present research also asks what educational, regional, and national methodological strategies have been used in Costa Rica. Finally, some results are examined, such as the case of the Tirrases district of the Curridabat canton, San José, CR.

5.2 Multifunctionality and Green Infrastructure (GI) Planning

GI is established on a series of diverse thematic axes such as mobility, public space, water resources, and biodiversity. In contrast to most gray infrastructure, which tends to have an anthropocentric objective, GI is distinguished by a multifunctional principle, meaning that it can promote solutions that benefit all living beings and their habitats. However, for this to happen, the ecosystem must be healthy and ecologically balanced, combining the ecological, social, economic, and cultural abiotic functions and the biotic of green spaces (Hansen & Pauleit, 2014, p. 517).

GI improves the ability of natural resources to provide ecosystem goods and services. An inclusive approach is encouraged, ensuring the use of spaces as efficiently and consistently as possible. According to Laura and Julián Quintero (2019), one of the most effective ways to construct GI is by territorial planning, since it makes it possible to investigate the compatible interaction between land uses and helps to determine the best places for the location of projects (p. 13).

Therefore, GI and BI networks interweave the urban fabric with ecological corridors, sustainable mobility, forests, parks, and gardens, among others. The city must be understood as an integral ecosystem, which supports a healthy environment and faces the effects of climate change, reducing floods, storing carbon, or avoiding soil erosion.

5.3 Elements That Make Up the Landscape: Patches, Mosaics, and Corridors

Scholars such as Forman, Dramstad, and Olson, specialists in landscape ecology, have studied the effect of species distribution concerning the size, arrangement, and shape of landscape elements such as patch, matrix, and corridor. Ecological networks emerge in response to large-scale fragmentation and loss of natural habitats, as a method of land use planning in population dynamics, community, and landscape ecology (Mackovcin, 2000, p. 211). Patches are defined as relatively homogeneous nonlinear areas with a certain degree of isolation, which differ from their surroundings and originate from residual introduced, or disturbed areas, and with existing natural resources, while the matrix is understood as a dominant element and connected in a landscape (Dramstad et al., 1996, p. 18). The corridors are linear, continuous, narrow elements that differ from the adjacent terrain on both sides, connect the patches, and allow the migrations of organisms between the bio centers (Dramstad et al., 1996, p. 35; Jelínek & Úradnícek, 2014, p. 89; Lindig, 2017, p. 147) (Fig. 5.1).

The GI is established on a series of diverse thematic axes such as mobility, public space, water resources, and biodiversity.

5.4 Green Infrastructure Problem in Mesoamerica

Authors such as Forman (1995), Mackovcin (2000), Snarr (2006), Guerrero (2005), and Vargas (2012) agree that global environmental deterioration is due to the excessive exploitation of natural resources. This exploitation is causing a vast ecological

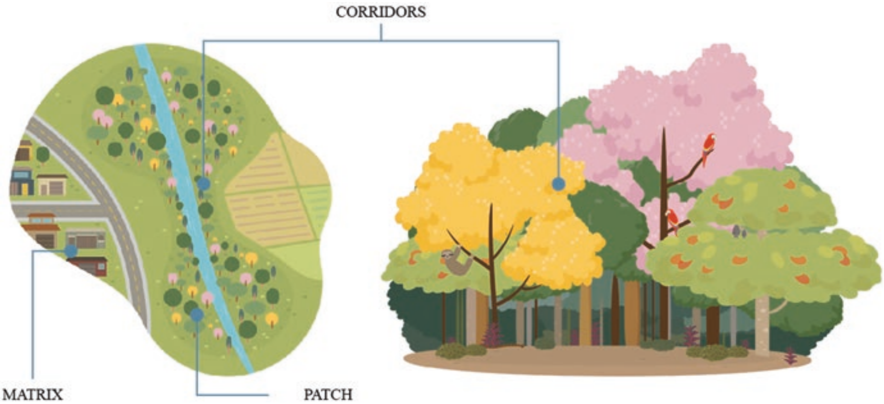

Fig. 5.1 Landscape elements. (Own elaboration, 2020)

imbalance, evidenced in a reduction of forests worldwide, with a rate of 1% of annual loss (according to Snarr, 2006).

The Mesoamerican region covers 0.5% of the earth's surface and is home to between 7% and 10% of the planet's biological diversity (Álvarez, 2013, p. 2), but it is not exempt from this situation. In recent years, it has suffered a considerable loss of its forests and natural areas. Among the principal causes are:

- Indiscriminate felling. Central America has had the highest deforestation rates in the world (according to Snarr, 2006).
- Intensification of agricultural monocultures and increasing illegal livestock.
- Urban development without environmental planning.
- Increase in transport infrastructure and number of vehicles.

Figure 5.2 shows the cuts imposed by transportation megaprojects to link the Pacific Ocean with the Caribbean Sea through infrastructure such as the 372-kilometer-long Guatemala Interoceanic Corridor. Besides, between El Salvador and Honduras, there are two proposals: the Central American Interoceanic Highway of almost 400 km and another of 280 km. Also, there is the projection of an interoceanic canal in Nicaragua, of 278 km, and a dry canal in CR, of 315 km. These canals will cause a break in ecological connectivity, as is the case of the Panama Canal, especially due to urban development on both banks, which prevent natural land migration for animals. The map also shows another of the most significant problems in the region, forest fires and agricultural burning, which affect forests and wetlands during the dry season.

As for the loss of plant cover, according to Fig. 5.3, Guatemala, El Salvador, and Belize were the countries most affected between 1980 and 2010. Nicaragua had suffered a considerable decrease from 6.86 million hectares in 1983 to 5.61 million in 2000. From 2011 to 2018, this same country lost 1.4 million hectares of forest, according to the analysis of the Humboldt Center (Guevara, 2004, p. 6). Central America is one of the most vulnerable regions in the world due to climate change,

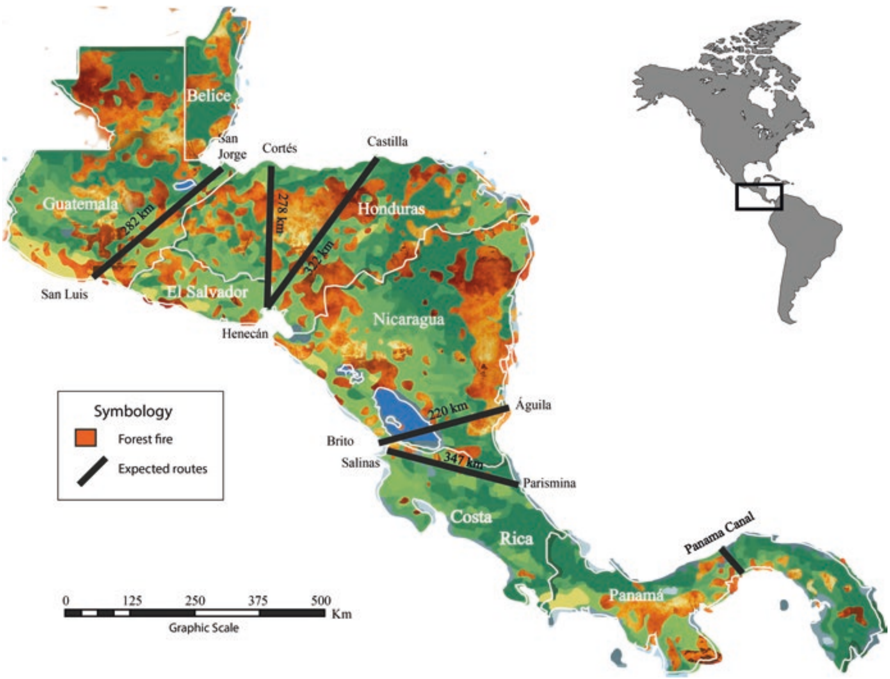

Fig. 5.2 Map of fires in Central America and interoceanic gray infrastructure projects. (Chaverri-Flores and Chaves-Hernández, based on NASA Image, 2018–2019 dry season, and https://archivo.eluniversal.com.mx/el-mundo/2014/corredores-interoceanicos-elsuenio-de-centroamerica)

with an increase in the frequency of droughts, hurricanes, and the El Niño phenomenon (CCAD, 2018, p. 42).

GI is a concept that has recently appeared on the agendas of regional government entities mentioned in their forums and conferences, as well as in the academic and professional environment. There is no consensus on the theoretical and conceptual framework in each country of the Mesoamerican region except for Mexico, which is the country that has led the GI strategy. In 2019, the Secretariat of the Environment of Mexico City (Sedema) executed the First Stage for the Participatory Preparation of the Green Infrastructure Master Plan for the City (SEDEMA, 2020). This is a reference consultation for the countries of the region, due to its potential for urban development planning. At the Latin American Sanitation Conference (Latinosan), specialists in ecosystem services pointed out the importance of applying GI as an essential element of water, energy, and food security in Latin America (Céspedes, 2019, p. 5).

Official literature and scientific production in Central America on GI are scarce, even though there are some notable exceptions, such as the studies carried out by the Municipality of Curridabat and the Centro Agronómico Tropical de Investigación y Enseñanza (CATIE). There is a growing interest in knowing the implications of working on GI based on theories, methods, and techniques.

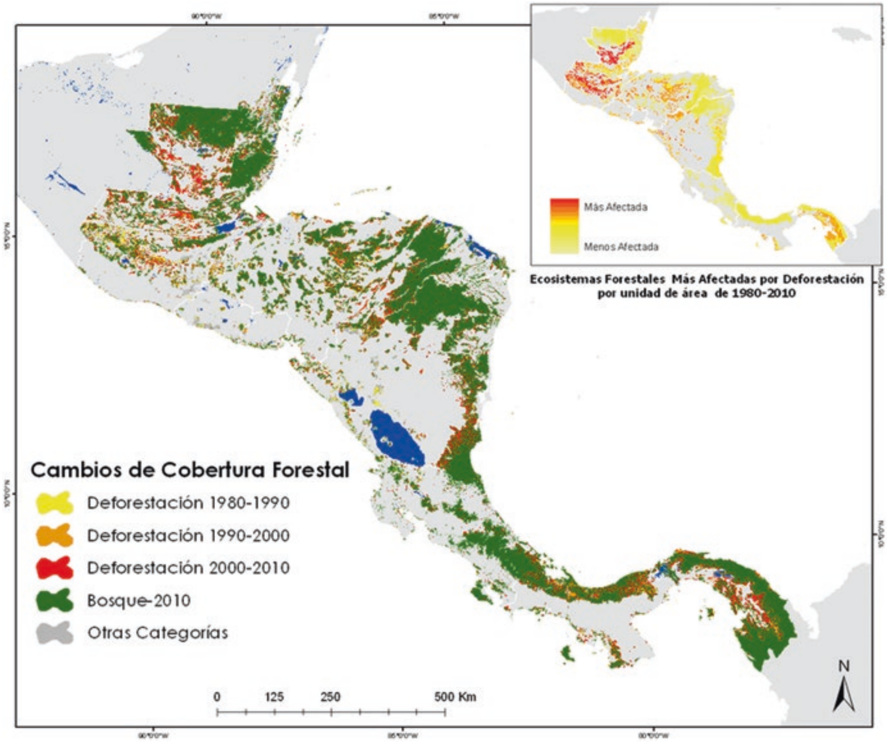

Fig. 5.3 Map of changes in vegetation cover. (http://www.fao.org/forestry/1366-04e3ade6e238e59fafbe0ccf81e66ec61, 2020)

In Central America and part of North America, according to Parrens (2013), the implementation of biological corridors (BCs) was born in 1997 during the 19th Summit of Central American Presidents. The Mesoamerican Biological Corridor (MBC) Consolidation Program encouraged governments to implement and adopt an institutional framework for managing BCs in each ministry of the environment. In this way, the MBC presents a political agenda determined by the vision of the common good of eight countries, Mexico (southern and southeastern states), Belize, El Salvador, Guatemala, Honduras, Nicaragua, Costa Rica, and Panama (Fig. 5.4), aiming to conserve the biological diversity of the region and implement sustainable human development; the MBC will act as a connector between North and South America. The MBC occupies 769,990 km^2 and extends from Darién to the Maya Forest in southeastern Mexico (Solís et al., 2003, p. 1). Its objective is to make the more than 550 protected areas of the system viable, which in part depends on the conservation of some intact natural habitats connected by strips of corridors with sustainable management. The MBC is therefore coherent with the integration of GI, since it is aligned with the objectives of biodiversity conservation, sustainable land management, and access to social assets such as water and the landscape.

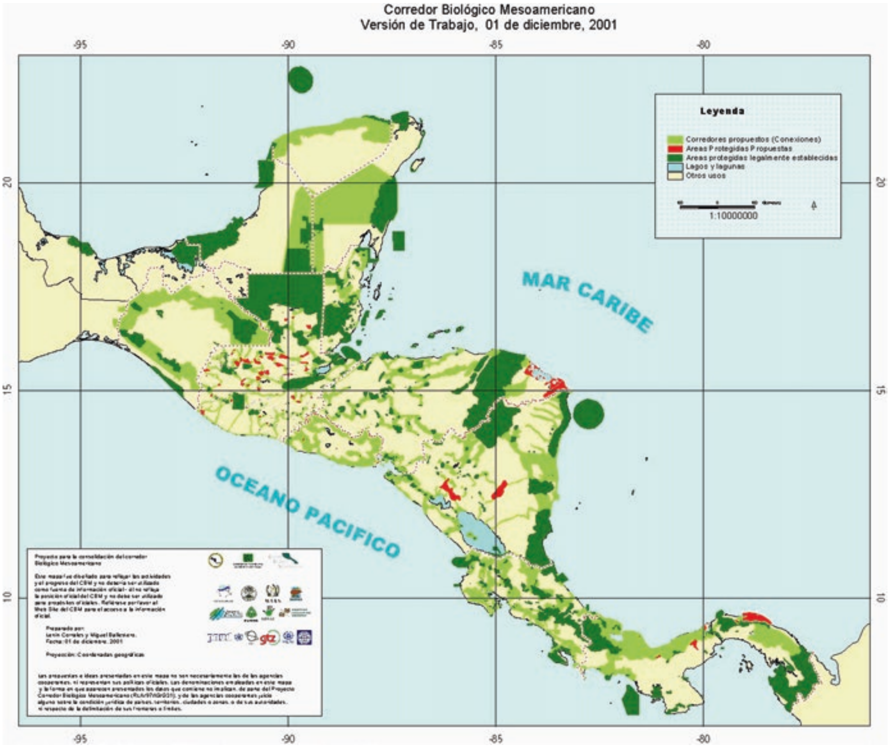

Fig. 5.4 Mesoamerican Biological Corridor (CBM). (https://ciencia.nasa.gov/science-at-nasa/2003/16may_biocorridors||https://ciencia.nasa.gov/science-at-nasa/2003/16may_biocorridors|, 2001)

The Central American countries have taken part in conventions, protocols, declarations, and initiatives related to the environmental issue and participate in global negotiations on the environment (Fraga, 2020, p. 7). Environmental management and climate change mitigation are promoted through the Central American Commission for Environment and Development (CCAD) as part of the Central American Integration System (SICA). The objective of the CCAD is to contribute to the reduction of human, social, ecological, and economic vulnerability by promoting actions that increase resilience (CCAD, 2018, p. 103). Generating GI projects and solutions based on nature is of vital importance, since the inadequate management of resources creates droughts and floods (SG-SICA, 2020). In 2009, the process for the preparation of the Regional Climate Change Strategy (ERCC) began with the mission of reducing adverse impacts, and its main lines of action are rational management of greenhouse gas emissions, comprehensive management of water resources, and strengthening the sustainable management of the CBM.

The main initiatives that have the potential to link with GI are summarized in the timeline in Fig. 5.5. The Paseo Pantera arose in 1990 due to fragmentation and loss of biological continuity and was a precedent for the CBM. Seven Central American

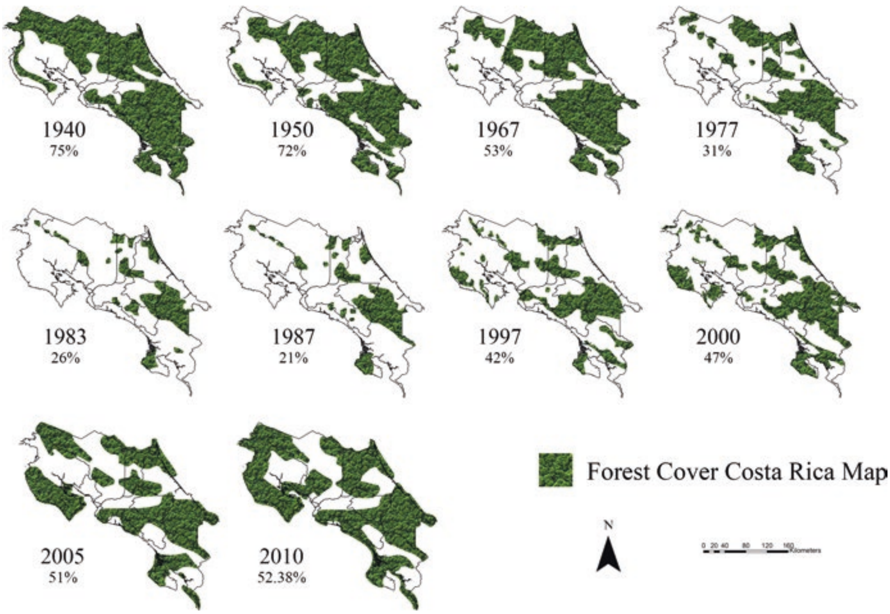

Fig. 5.5 Evolution of forested coverage in CR. (Source: Own elaboration based on MINAET, National Forest Financing Fund (FONAFIFO, 2012))

countries made it official in 1997, while Mexico joined the program in 2002 by including the states of Chiapas, Quintana Roo, Yucatán, Campeche, Tabasco, and Oaxaca. Founded in 2006, the Pantera Corporation focuses primarily on consolidating the Jaguar Corridor Initiative (ICJ), which seeks to protect jaguars across 6,000,000 km^2, from northern Mexico to Argentina. The latest milestone in the consolidation of the CBM is the creation of new connectivity figures such as the Interurban Biological Corridors (CBI) in CR, which enhance GI in urban environments.

5.5 Background on Green Infrastructure and Inter-City Biological Corridors in CR

Costa Rica is recognized internationally in the field of environmental protection. Since the middle of the twentieth century, national parks and reserves have been created throughout the country. However, the process to conserve and recover the loss of forest that was lost from the 1950s to the 1990s has been slow. According to Carlos Manuel Rodríguez, "Costa Rica has doubled its forests in the last 30 years and the rest of Central America has lost around 30 percent" (Alonso, 2020).

In 2006, CR created the National Program for Biological Corridors (PNCB), as a strategy for the conservation and sustainable use of biodiversity, from the perspective of functional and structural ecosystem connectivity (SINAC, 2018, p. 12). The hierarchical line of the PNCB consists of the following structure:

1. Regional Program for the Consolidation of the CBM
2. National Network of CB in CR
3. Regional Programs of CB in Conservation Areas
4. Local CB Councils

By 2016, the PNCB had 44 official CB initiatives distributed throughout the country and 4 CBs in the process of meeting the requirements to be made official. CR, with an area of 51,100 km^2, has 33.1% of its territory destined to be biological corridors (16,927 km^2) and 26.5% of protected wild areas (13,545 km^2) (SINAC, 2018).

The inclusion of the Interurban Biological Corridors (CBI) program within the PNCB began in 2017 with an executive decree. The promoters of this initiative are SINAC, the National Power and Light Company (CNFL), international cooperation organizations, state universities, and local actors, among others. The CNFL has participated in the creation of a network of CBIs since 2008, seeking to supply the quantity and quality of water for hydroelectric plants.

The CBIs are urban territorial extensions that provide connectivity between landscapes, ecosystems, and modified and natural habitats that interconnect micro-watersheds and green spaces or wild protected areas. The first official CBIs in Costa Rica were planned based on hydrographic systems. This action coincides with a conception of GI strategic planning, understanding the macro-scale as the urban scale of hydrological basins and sub-basins (IMPLAN, 2017, p. 196). The entities in charge of the implementation of the CBIs see GI as an effective "multi-approach" strategy to address viable solutions in urban space.

The creation of 12 CBIs, of the interurban or suburban type, is being planned. The CBI Río Torres Biosphere Reserve (CBIRT-RB), created in 2011, is located along 26 km in the micro-basin of the Torres River, in the country's metropolitan area. The CBI María Aguilar from 2019 establishes its biological and structural connectivity following the basin. CBI Garcimuñoz was officialized in 2019 and created an environmental link along several rivers: the Poás, Grande de San Ramón, and the Virilla, joining a national park, a protective zone (El Rodeo) passing through the Huetar-Quitirrisí indigenous territory, and four other protected zones.

The Municipality of Curridabat, an institution that has part of CBI María Aguilar within its territory, implements GI methodology. The study, called "Evaluation of green infrastructure and ecological connectivity," developed by CATIE in conjunction with the Municipality, is one of the first cases in the country in which the interpretation of the GI concept became a reality. The infrastructure is defined as a network capable of providing to the urban system with elements and ingredients that are capable of solving urban problems by addressing the challenges of climate change. This is carried out through the active interaction of the built environment with the natural, and it is designed and managed to provide a wide range of ecosystem services and protect biodiversity (Municipality of Curridabat, 2019a, b, p. 10).

Other relevant milestones are the promulgation of the Costa Rican Landscape Charter carried out by the Association of Costa Rican Landscapers in 2010, a manifesto oriented towards an understanding of the concept of landscape and the relationship of professionals and society in general with the environment. The Landscape Observatory of the University of Costa Rica (UCR) and the CNFL have led the creation of catalogs. In 2017, as an input and planning instrument for municipalities, they created the Atlas of Landscape Units of the Greater Metropolitan Area (GAM).

The GAM has enormous potential in the rural-urban relationship because many areas of the periphery have different categories of protected areas as well as traditional crops. Forest zones make up green systems at the regional level, providing environmental services such as rain infiltration, aquifer recharge, and organic agriculture, among others. At the community level, there are possibilities for reconfiguring streets to create greenways, and green-blue infrastructure, integrated these into existing green belts. For all this, it is essential to promote landscape-planning methodologies that incorporate GI.

5.6 GI Educational Methodologies

In the educational field, state-provided higher education seeks the integration of GI with the CBI by means of planning, design, and management of university grounds. This occurs in several ways: (1) linking campuses through structural and functional connectivity with the CBI, (2) carrying out research related to the topic, (3) including GI in the teaching plans as a methodological resource in undergraduate and graduate degrees. As for point one, public universities are playing a significant role in ensuring ecological connectivity. The CBIs are an opportunity to integrate GI into the urban fabric through green areas, allowing an inclusive, resilient, and carbon-neutral territory visualization.

The National University (UNA) is directing part of its scientific potential to generating a CBI proposal in the micro-basin of the Bermúdez River. The Technological Institute of Costa Rica (TEC) has promoted the establishment of a bio-corridor in the Cartago campus, which is within the CB Ribereño Interurbano Subbasin Reventado Aguacaliente (COBRI SURAC) created in 2016. The UCR has connectivity with the CBI Río Torres, to deal with problems related to water sanitation, air quality, urban mobility, and the promotion of biodiversity; its new buildings incorporate some GI solutions like delay lagoons.

In 2017, an urban landscape and environmental protection proposal was made for the sports facilities of the UCR with the implementation of GI (Fig. 5.6), incorporating the systems of functional units, connectivity, protection and ecology, edge, and joint.

In the field of research, a plant survey was carried out on the campus of the Rodrigo Facio Headquarters of the UCR, establishing an inventory of the biodiversity of tree, shrub, palm, and herbaceous species with a high degree of detail in

Fig. 5.6 Macro connectivity proposal for UCR. (Own elaboration, 2017)

botanical, geographical, and landscape description. The university also created a table of landscape use as a species analysis tool. The efforts of this fieldwork in measurements and surveys were unified with the Carbon Neutral Project, enriching the natural asset base of the CBI Río Torres Biosphere Reserve.

In the field of teaching, from the UCR and TEC Schools of Architecture, in coordination with other schools such as Biology, Geography, Forestry Engineering, and Anthropology, substantial problems of consultation and validation are being addressed through participatory processes that allow feedback with local governments, associations, organized groups, and the community in general.

Design and planning exercises have been proposed with themes that allow for various conceptual approaches such as landscape studies, biophilia, GI, CBI, and regenerative design or combinations. The methodological approach might vary according to the particularity of the academic exercise, the object of study, and the scale of the context, establishing a logical sequence of processes and tools based on the GI, which will be explained below.

5.7 Framework

Every landscape design project begins with a referential framework that studies the state of the art, conceptual background, and trends with prospective approaches. Case studies that have resolved related issues or problems at the national and international level are also analyzed. Field trips to built works and sites of natural and heritage value are included (Fig. 5.6). Figure 5.7 shows a professional proposal integrating the GI into a productive and leisure project. This design considers sustainability aspects such as rational use of water, conservation of bees, and consolidation of protected areas.

Fig. 5.7 Aerial photo of an orchard garden located in San Antonio de Escazú, San José de Costa Rica. (Design by Guillermo Chaves and Laura Rodríguez, construction by Elmer Arias MELMET S.A (Own elaboration, 2020))

5.8 Multiscale Diagnosis

The diagnosis and the proposal vary depending on the scale and complexity; however, the multiscale is recommended using geographic interpretation tools, where generality and connectivity are studied on a macroscale and specific aspects on a meso- and micro-scale. The scales of the GI can be regional, cantonal, neighborhood, or site, differentiating their analysis according to their condition of the area: predominantly natural, rural, suburban, or urban (Fig. 5.8). The purposeful results are oriented to regional planning, urban plans, master plans, or site design.

The analyses with overlapping information are carried out with the necessary layers for each study and can number more than 40 in the process of planning and officialization of the CB and GI. For example, maps of slopes, watersheds, conservation areas, and life zones are elaborated. Satellite information technologies and fieldwork can be used, which provide criteria for the assertive interpretation of the territory, such as:

- Areas that make up the GI.
- Identification of biodiversity nuclei.
- Base inventory of natural assets: these comprise natural elements, such as forests and wetlands, or built components such as trails, whose value partially derives from the natural landscape that surrounds them (Walker, 2015, p. 115).

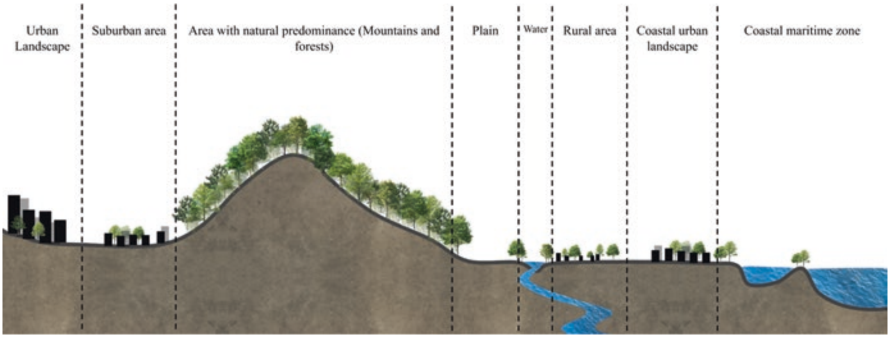

Fig. 5.8 Green infrastructure scale

- Definition of planning units.
- Ecological and socio-environmental connectivity networks.
- Indicators and monitoring system.
- Actor Map.

Multiscale diagnostics can be addressed using the following methods:

5.9 Site Analysis

Edward T. White (1983, p. 1) proposes various components and diagramming tools for site analysis. The work defines contextual analysis as a pre-design investigation, an activity that focuses on the existing, imminent, and potential conditions in and around a project site. The methodological structure can vary considerably, depending on the objective, including "site location, size, shape, contours, drainage patterns, zoning and setbacks, public services, important features on the site, surrounding traffic, neighborhood patterns, views to and from the place and the climate" (White, 1983, p. 6). The following are proposals in the Landscape Design workshops of the UCR and the TEC:

- Socio-historic analysis and evolution of the place, reconstructing the urban image with the support of aerial photos, historical pictures, and verbal or written memory.
- Geophysical analysis of hydrology and topography.
- Environmental analysis.
- Socio-economic analysis.
- Mobility analysis: infrastructure, transport, and connections.
- Territorial urban analysis.
- Landscape analysis.

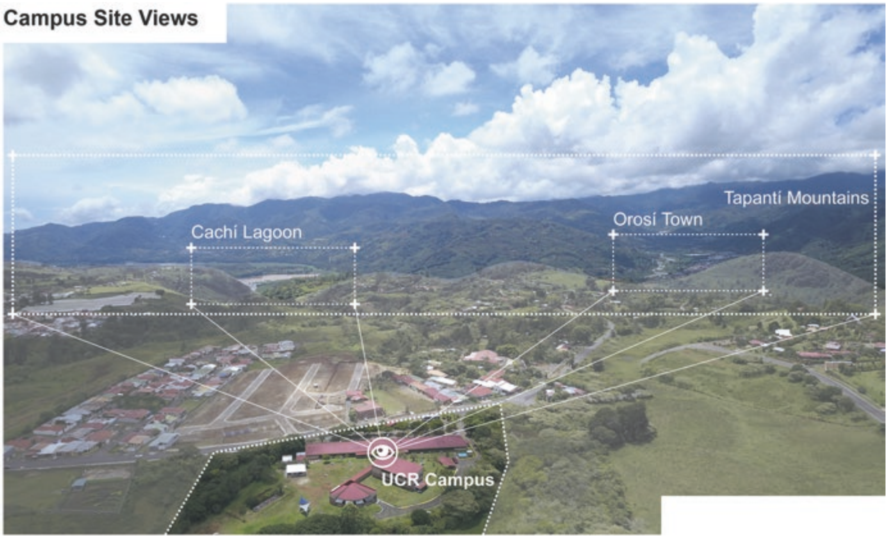

Fig. 5.9 Visual analysis in Paraíso UCR University Campus (Master's Degree in Landscaping and Site Design, UCR) (Luis Solano Monge, 2017)

The latter includes the study of scenic sites. Figure 5.9 shows a visual analysis performed in the Postgraduate Degree in Architecture.

At this stage, information is collected from both a qualitative and quantitative points of view. Figure 5.9 shows the design process followed by a master's student in which, after specific analyses (visuals, vegetation cover, among others), he developed a zoning proposal as part of the preliminary proposal.

5.10 Landscape Units

Landscape units (UPs) are portions of the territory with the same character, delimited by their most outstanding features and grouped into a limited number of categories (Jankilevich & Aravena, 2012, p. 10). The methodology of the Landscape Observatory of the UCR uses the catalogs of Catalonia, defining the UP at national and GAM level. The catalogs are configured from the landscape, visual, and territorial conditions, and the landscape quality objectives aim to achieve the desired landscape. Among the layers of analysis, social perception and identity and intangible heritage are incorporated. UPs can be a methodological tool within GI.

5.11 Ecosystem Services

GI is valued through ecosystem services that derive arising from the functions of nature.

According to the CICES, they are grouped as follows:

1. Regulation and maintenance services.
2. Provisioning services.
3. Cultural services (Calaza, 2019, p. 46).

They are part of the definition of strategies and plans to generate indicators and systems for monitoring.

Ecosystem services promote social interaction and, together with GI, provide multifunctional value. Scientific evidence shows the relationship between GI and the physical and mental health of the human being (Turner et al., 2014). Figure 5.14 is an example of these services. The vegetation cover of Fincas 3 and 4 provides fixation and storage of CO_2, erosion control, and also generates a sense of belonging and identity with the strikingly colored trees, which attract interest during walks (Fig. 5.10).

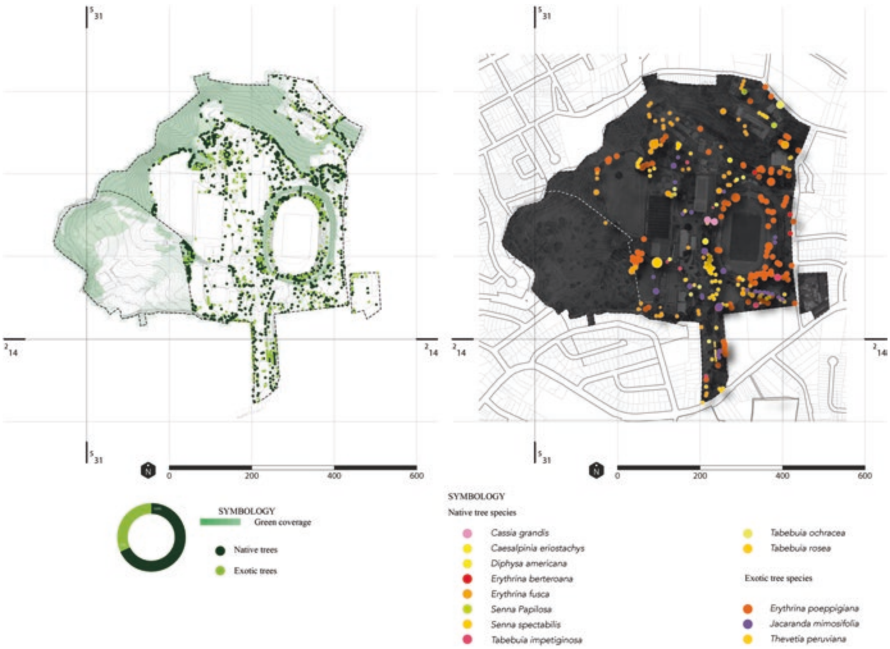

Fig. 5.10 Maps of native and exotic trees, striking flowering and threatened and vulnerable trees UCR University Campus. (Chaverri et al., 2017)

5.12 Participatory Management: Perceptual and Heritage Values

As an antecedent to participatory processes, there is urban image methodology, as proposed by Kevin Lynch. Through fieldwork with the inhabitants of the area, the researchers define milestones, nodes, paths, borders, and neighborhoods. In the workshops, they develop various tools like surveys, participatory workshops, interviews, counts and flow maps, collecting experiences, as well as the valuation of natural and cultural heritage. The historical corridors are used as an instrument to understand the evolution of the image. The intention is to promote community participation and raise awareness of the conservation of representative architecture and recover historical memory and the local and regional identity (Malavassi, 2008, p. 3). Mapping and catalog cards are used for systematization.

Landscape research takes into account tangible and intangible aspects that protect historical, architectural, artistic, and symbolic values, determining cultural events and social behaviors according to intensity of use, schedules, and seasons. Figure 5.11 shows a survey prepared to set out the worth of natural spaces and identity elements according to the user. Citizen participation is proposed from beginning to end of the processes for validation, feedback, and dissemination of results.

5.13 Conceptualization of the Problem and the Response

The concept expresses the underlying idea in the design and guides decisions in a determined direction, organizing and excluding variants (according to Muñoz, 2008, p. 13). The conceptual approach to the problem and the response to it guides the correct justification and achievement of the objectives.

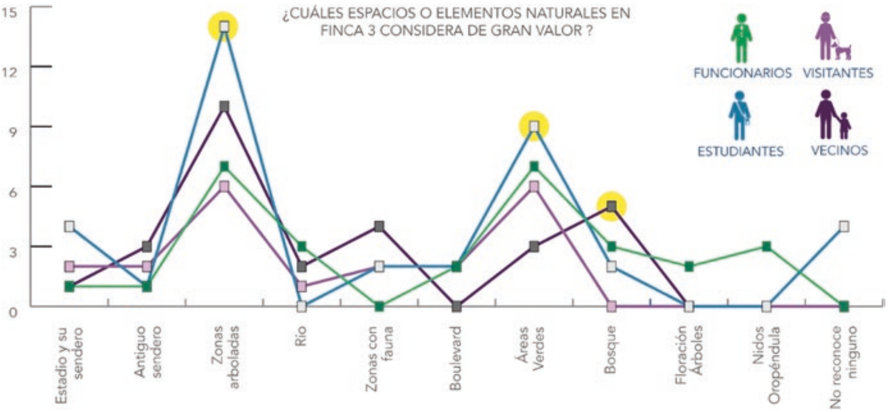

Fig. 5.11 Interview diagrams on natural elements and species of Finca 3. (Own elaboration, 2017)

After the analyses, it is essential to be able to generate a synthesis that provides the conceptualization of the problem, which arises from questions such as: What works well? What are the weaknesses or shortcomings? How is GI structured in a particular context? SWOT analysis or related tools are also useful to guide GI strategies. From this analysis, the guidelines of the plans and challenges to be addressed emerge.

Regarding the conceptualization of the response, a strategic plan includes the mission, vision, values of the strategy, guiding principles, and premises of GI. At the site scale, the answer arises through a generating idea, field geometry, formal and ecological guidelines, and definition of large functional blocks, among others. For GI, the following subsystems are used as a methodology to analyze the current situation and provide solutions:

- Social system
- Mobility system
- Metabolic system (energy production)
- Biological system
- Hydrological system: basins, sub-basins, hydric recharge, aquifer, infiltration, hydric balance, underground water, among others
- Geological system

5.14 Multiscale Proposal

At this stage, the idea is put into practice through master plans, strategic plans, site plans, and management. In the proposals, it is pertinent to define what should be retained, reinforced, accentuated, reduced, modified, or eliminated (White, 1983, p. 10).

Urban GI includes urban forests, transition spaces, buffer zones, borders, and ecotones between green areas scattered throughout the city. The proposals promote the connection of the cores and other network components within the CB matrix. Figure 5.12 shows the GI and BI proposals for Farm 3 and 4.

At the same time, the enjoyment of sustainable mobility is sought, preserving the views of the most valuable landscapes in the territory, facilitating the transition between urban and rural. By projecting BI and biophilic design, it is possible to integrate solutions based on nature (SBN), which contribute to air quality, water management, and public health, among others.

At the site plan scale, a landscape program is defined, as well as the flora and fauna palette. Besides, spatiality is established, with the support of interpretive instruments. Figure 5.13 represents a proposal for the Paraíso Campus of the UCR, achieved through the projection of different layers and strategies for the integration of external space.

Fig. 5.12 GI and BI proposal for Finca 3 and 4. (Source: Own elaboration, 2017)

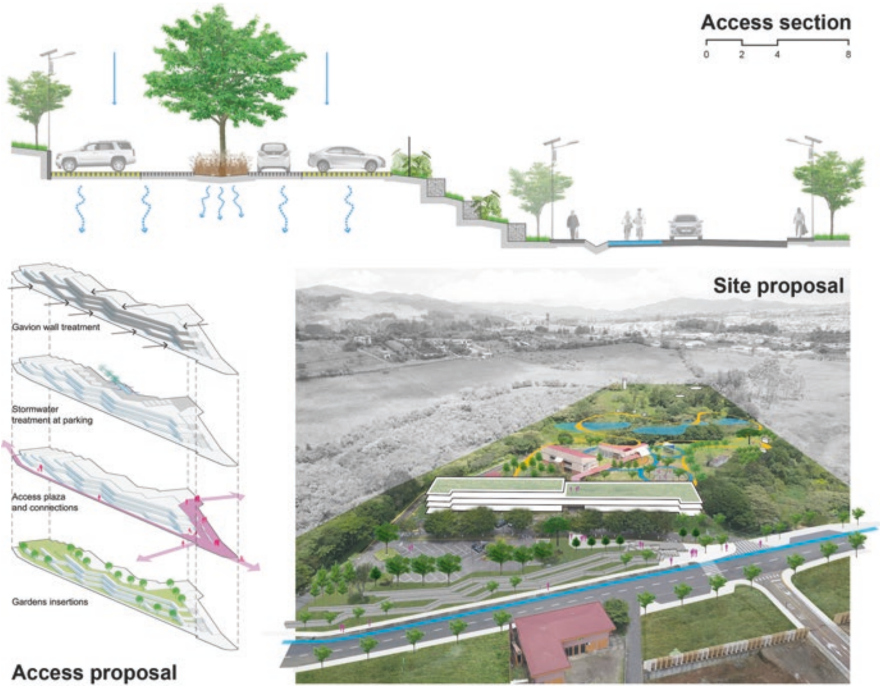

Fig. 5.13 Proposal in the Paraíso Campus UCR. (Luis Solano Monge, 2017)

5.15 Case Study: Tirrases Curridabat

The UCR School of Architecture is carrying out an investigation in the institutional sector of Tirrases, where one of the objectives is to establish technical criteria for the definition of GI. In the educational field, GI planning and design exercises have been carried out in the area.

Tirrases is a district in the canton of Curridabat (Fig. 5.14), located southeast of the city of San José. It is known for having large marginal urban sectors that developed from the 1970s on the periphery of the Río Azul landfill. At present, 25% of the district's inhabitants live in poverty (Municipality of Curridabat, 2012).

Tirrases has 4.3 m^2 of green space per inhabitant, while the canton has 7.5 m^2, which is half of the minimum recommended by the WHO (Municipality of Curridabat, 2019a, b, p. 5). It is the district with the lowest area of green spaces due to the occupation of slopes, riverbanks, and other lands. "Globally, and more specifically, in developing cities in Latin America and South and East Asia, there has been a shift towards more private and semi-private ownership of GI, which potentially limits the equity of access to the physical environment for some citizens" (Mell et al., 2019, p. 241).

Starting in 2015, the Municipality of Curridabat created the Ciudad Dulce program, which seeks to improve the well-being of citizens by increasing their contact with nature. Within this framework, some important instruments have been developed for the conformation of the GI, such as protocols for calm sidewalks, plant guides, biodiversity monitoring systems, and ecosystem services.

GI planning transcends geopolitical divisions, so it is essential to consider protection systems associated with the study area to reduce fragmentation. At the regional scale, a biological corridor, two protective zones (ZP), and five CBIs have been declared by SINAC (Fig. 5.15).

From the macro-scale, the connection of the most representative patches of biodiversity is proposed, such as the ZP Cerros de la Carpintera, Loma Salitral, and El Parque la Colina (Fig. 5.16). This set of green areas is relevant for the zone, since the first two have several species of endemic flora within their biodiversity inventories, and the park was named the lung of Tirrases. In this framework, it is proposed

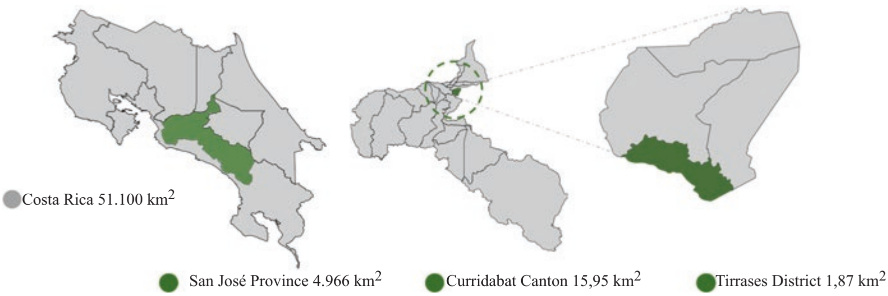

Fig. 5.14 Study area location map. (Source: Own elaboration 2020)

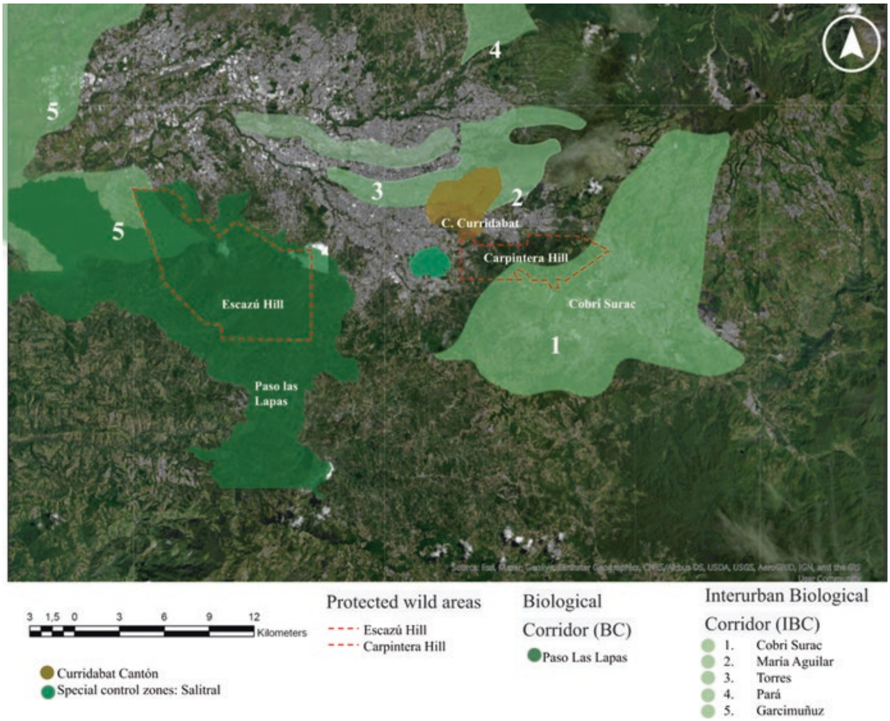

Fig. 5.15 Cb, CBI, and ZP map. (Authors, 2020)

that GI should consider these habitats and their connectors as urban-ecological systems.

At the district level, GI and BI are integrated into the institutional sector and the ecological connectivity proposal with the creation of corridors associated with rivers and the consolidation of patches (Fig. 5.17). The area includes the Technical High School, the Human Development Center, the Care Center, and other institutions (Fig. 5.18).

The socio-environmental technical criteria to define GI were:

- Functional connectivity of the links analyzing their location, width, and border effects.
- Definition of the biological and social purpose of the corridors, as well as the heritage elements that compose it.
- Establishing categories of citizen participation in coordination with the municipality and educational centers.
- Participatory processes to define intervention priorities, generating empathy and territorial identity and a sense of group connection.
- Long-term vision establishing stages, evaluation indicators, and monitoring systems. Some signals may be the efficient public space index and the counts of species diversity before and after the intervention.

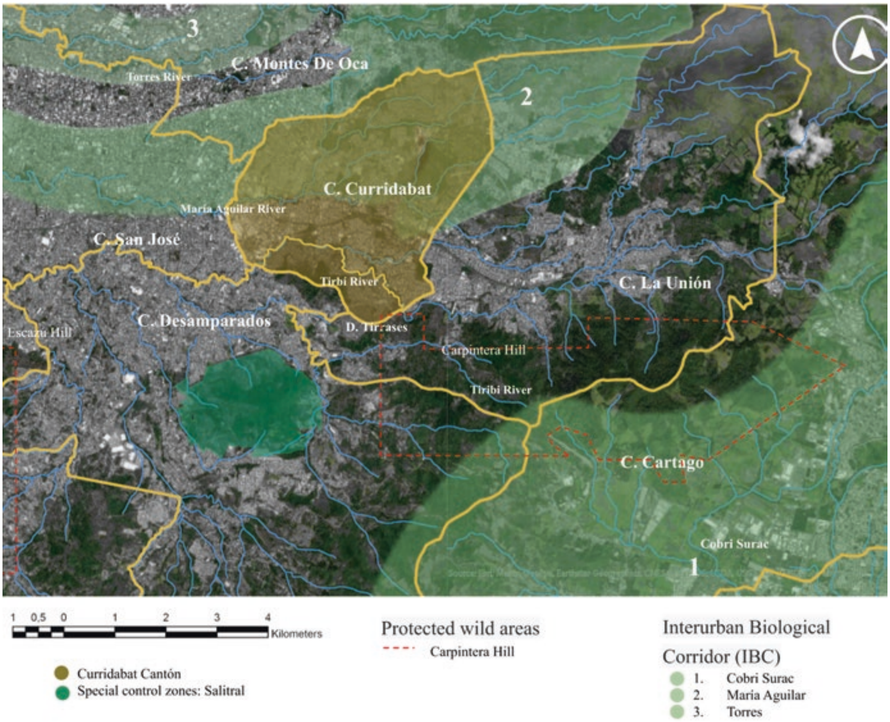

Fig. 5.16 Cb, CBI, and ZP map. (Authors, 2020)

Regarding the academic experience, different approaches have been addressed in the area. Multidisciplinary teams proposed landscape units at different scales (Figs. 5.19 and 5.20) to present landscape quality objectives, including GI and BI in each characterized unit. The latter worked from different scales and representation techniques. In Fig. 5.21, a series of green connectors are proposed at the level of streets, sidewalks, wildlife crossings, and gardens, shown in 30 photomontages with conceptual images.

The formation of parks, boulevards, and gardens, both public and private, are essential components of GI. The orchid garden (Fig. 5.21) is an excellent example of how small green spaces can be connected using strategies that allow rain infiltration to the ground and the use of various species that generate a more pleasant microclimate. Doubling the vegetation cover could reduce the temperature by up to 3 °C, and this is the proposal that creates the most cooling benefit in suburban settings (Broadbent et al., 2019).

Fig. 5.17 Map of Tirrases and immediate context. (Own elaboration 2020)

Fig. 5.18 Academic tour Technical High School. (Chaverri, 2018)

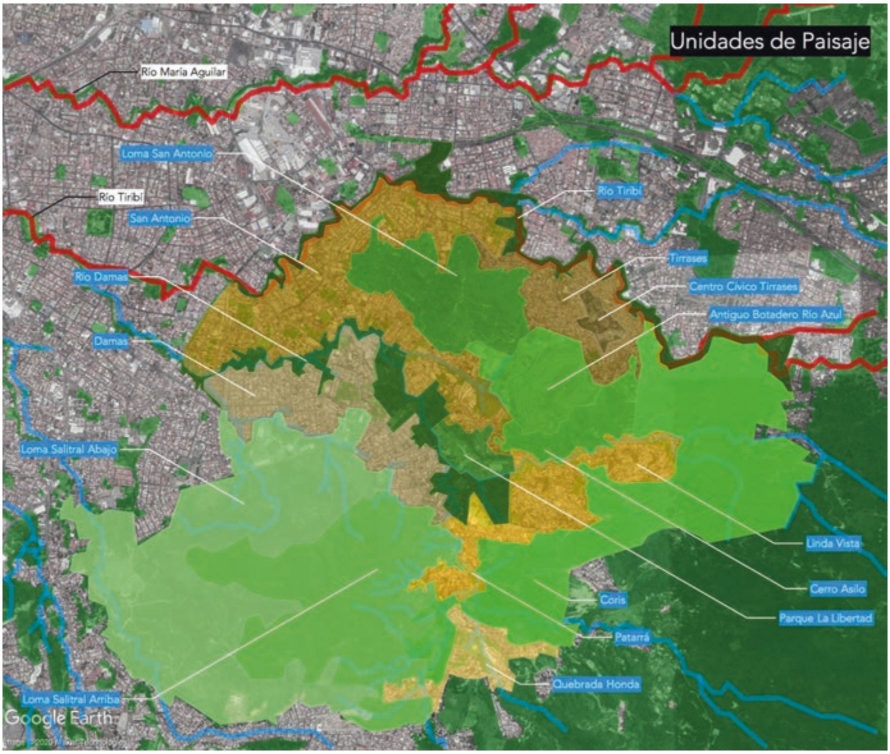

Fig. 5.19 Map of landscape units at the macro-scale. (Source: Alvarado, 2020)

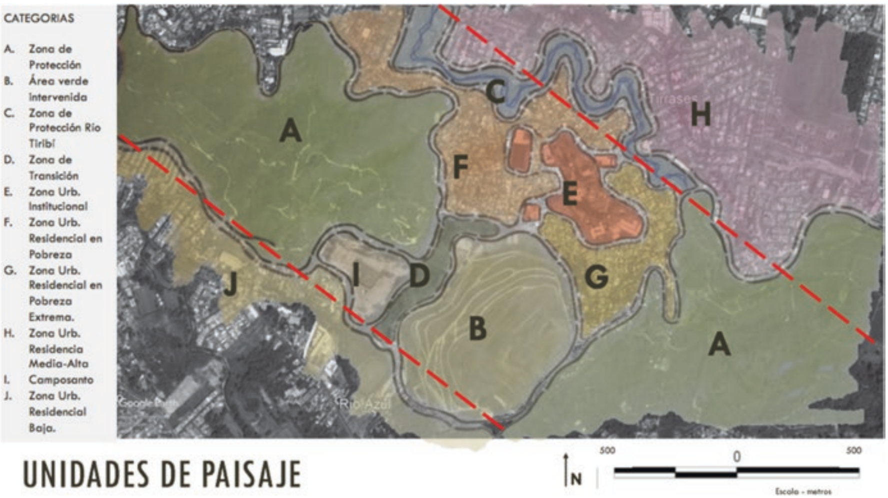

Fig. 5.20 Map of landscape units at micro-scale. (Master's Students in Landscaping and Site Design, 2018)

Fig. 5.21 Proposal by GI Tirrases. (Araya, 2018)

5.16 Conclusions

GI comprises an interconnected network of natural and cultural systems that link the population with their territory, providing ecosystem services and opportunities to integrate them into educational programs at all levels. It constitutes a point of reference to generate territorial planning decisions. GI is understood as an important multifunctional instrument for the management of the territory (Cantó, 2014, p. 232). It is a way of supporting urban environments by providing particular benefits in two key areas, adaptation to climate change and conservation of urban biodiversity (Corrales, 2019, p. 76).

Among the main findings of this work were that the corridors, in addition to offering ecological protection, also perform landscape, urban, and social functions. The incorporation of the CBM and the CB of Costa Rica in this network constitutes new systems that, with institutional support, find agreement with green infrastructure. Multisystemic design, multifunctionality, and multiscale analyses and proposals constitute methodological tools that are usable in areas of social marginality. In this way, GI planning should be projected from a global vision down to the site scale.

The contribution of this work constitutes the historical account of green infrastructure in Mesoamerica and CR, a newly introduced topic in the region, as well as the presentation of replicable design tools in landscaping. A priority is to incorporate GI into legislation for land use planning and to prevent the loss of an important part of the natural and cultural history of the territory. It is essential to unify efforts and knowledge both environmentally and socially, from local and ancestral knowledge to academic and scientific investigations, creating synergy with the CBIs, systems of protected areas, and other cultural assets of heritage value.

Multidisciplinary research and university education are essential to generate the contribution of new knowledge and methodologies with a tropical focus. From the educational field, the proposal is to train professionals that are more aware of GI and that possess in a comprehensive and multi-scale vision of their design projects. Faced with the environmental emergency, a paradigm shift that incorporates green infrastructure in all areas of territorial action is urgent.

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Chapter 6
OMBÚes. Comprehensive Understanding of Nature and Green Infrastructures

Ana Vallarino Katzenstein

Abstract This chapter will discuss theoretical-methodological guidelines to promote the comprehensive understanding of nature, a necessary condition for success in landscape planning with green infrastructure. A set of ideas will be presented based on the articulation of the cardinal principles of the complexity paradigm with conceptual, thematic-disciplinary, tactical, and strategic aspects. Several lines of work developed within the Universidad de la República, Udelar (University of the Republic), will be taken as reference, with emphasis on initiatives coordinated from the Facultad de Arquitectura, Diseño y Urbanismo (FADU, Faculty of Architecture, Design and Urbanism), derived from the theory of articulation of moments and the project OMBÚes-values associated with nature.

Keywords Principles of complexity · Human condition · Nature · City · Collaborative work

6.1 Introduction

> L'horizon, surligné d'accents vaporeux, semble écrit en petits caractères, d'une encre plus ou moins pâle selon les jeux de lumière. De ce qui est plus proche je ne jouis plus que comme d'un tableau, De ce qui est encore plus proche que comme de sculptures, ou architectures, Puis de la réalité même des choses jusqu'à mes genoux, comme d'aliments, avec une sensation de véritable indigestion, Jusqu'à ce qu'enfin, dans mon corps tout s'engouffre et s'envole par la tête, comme par une cheminée qui débouche en plein ciel. (Francis Ponge)

The epigraph that heads this section outlines the approach that guides this proposal, an idea of a multiscale landscape, where multisensory perception is fundamental, a back-and-forth between practices and representations is manifested, and where a

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special bond between nature itself and that of the environment is established. It manifests a symbiotic relationship between poetry and desire, origin, and purpose of each other, a necessary condition for personal fulfillment and the quality of life, intimately linked to the ways of inhabiting the city.

The basic idea is to contribute to landscape design from a conceptual and methodological point of view, for which the link between research and creative processes is key. One possibility is for research to be a preliminary stage of project instances, providing standards and guidelines for the design, planning, and management processes. Another option is for the project to be the object of research, considering creation in a broad sense, which includes diverse actors, practices, and representations. Finally, at other times the project is part of the research method (as a stage or as a tool), proposing support networks for the interpretation of reality.

The landscape project is not a finished product, but is a process that involves living organisms and the complexity of the environment; it includes the sociocultural, paying special attention to intersubjectivities. Management and handling should be part of the design. Theory and professional practice and that of the trade are very close in the landscape architect.

Landscape architecture develops its field of work at the join between the environmental and the architectural; it privileges relationships over the objects themselves, especially taking into account the articulations and unstructured spaces. However, it unfailingly includes a creative process.

Likewise, there are intimate links between project and research activities. Both articulate imagination, knowledge, and organization, aiming to create products that improve the quality of life. They are indispensable tools of innovation.

Thus, "research is not erratic, but methodical; there is not only one way to suggest hypotheses, but many ways: hypotheses are not imposed on us by force of facts, but rather are invented to account for the facts" (Bunge, 1997, p. 32). Regarding the creative processes associated with the project, they could be interpreted "as a recursive process of continuous formulation of interrelated formal hypotheses. And in this sense, a hierarchy of hypotheses will be recognized, […] leading towards configurations of less abstraction" (Scheps et al., 1996, p. 34).

Articulating research with design implies instances in a loop, in which it would be convenient "to design to research and to research to design" (Pantaleón, 1997). This loop should also be the foundation for university functions – research, teaching, and extension – to attend to the social function of landscape architecture. Returning to Arocena: "we want to revitalize this idea of a Latin American University that combines teaching, extension and high-level research, at the service of society and with the active participation of students" (Arocena, 2008).

The proposals that will be developed in these reflections are supported by works framed in the program "Landscape and public space" of the Institute of Design, idD FADU Udelar. A fundamental pillar, from a conceptual and methodological point of view, is the "Theory of articulation of moments (TAM) applied to the city/nature relationship" that will be developed in the conceptual framework. Another pillar is "OMBÚes-Values associated with nature," a long-term university project that articulates research, teaching, and extension. It aims to develop an ICT in education meant to raise awareness about the value of landscapes and local histories in interaction with natural components, focusing on vegetation in general and ombúes (Phytolacca dioica) in particular, strengthening local and national identities. A content portal (www.ombues.edu.uy) and an app for mobile devices (for georeferencing of ombúes) suitable for the computers that children have in public schools are being developed. Workshops with schools are being held, destined to value everyday and occasional relationships with nature.

A basic premise of our work is empirical research. It enables us to study phenomena in their real-life context and to use multiple sources of information. A key technique is the case study method (Collerette, 2004) as it emphasizes the complexity of social systems.

Finally, there is an ethical position as the underlying layer for this proposal. For that reason, I bring up the classification of values that Kevin Lynch proposed in relation to urban policies. Five groups were identified according to the way in which these are made explicit, are achieved, are obtained in practice, or can be measured: first, the "strong values" are made explicit as political objectives and are frequently cited; although they do not have great ambitions, they generally materialize. Second, the "illusory values": although they are generically similar to the former, they fail to come about. They do not take place or materialize because of their pluri-, trans-, and interdisciplinarity, and therefore the complexity of the intra- and inter-institutional relationships is required, or simply because they are only theoretical facades without supportive intentions. Third, «weak values» are frequently cited, but they play a rather decorative political role since it is not clear how to achieve them. This is due, as with illusory values, to the complexity of the factors involved. Fourth, the "hidden values" are not clearly exposed, but are fervently desired and clearly achieved. Finally, there are the "relegated values", which are not a priority since they have dubious, confusing, or impractical relationships with urban policies (Lynch, 1985).

6.2 Conceptual Framework

The general framework of this approach is the paradigm of complexity. It is based on an epistemological and conceptual framework that emerges from systemics and constructivism, focusing on actors and meanings. It is based on three basic principles: the dialogic principle, the recursive principle, and the principle of the hologram (Mucchielli, 2004, pp. 23, 24), which will organize the Decalogue of the following section.

TAM proposes a dynamic dialog to address the complexity of reality, defining primary unidualities (the two faces of a Moebius strip). These are represented by opposite and complementary moments. Moments (in the mechanical sense) are the product of forces by distances. Applied to the city/nature relationship, it takes man as an implicit pair of forces, both belonging to and external to nature (since the human species belongs to nature and at the same time nature is taken as a cultural construct). The city and nature make up the explicit pair of forces (Fig. 6.1).

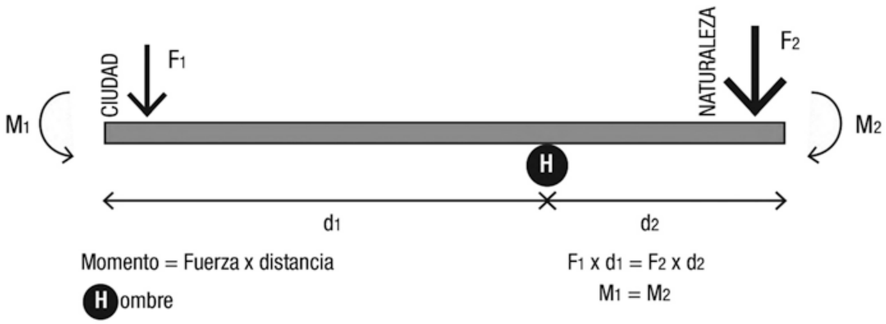
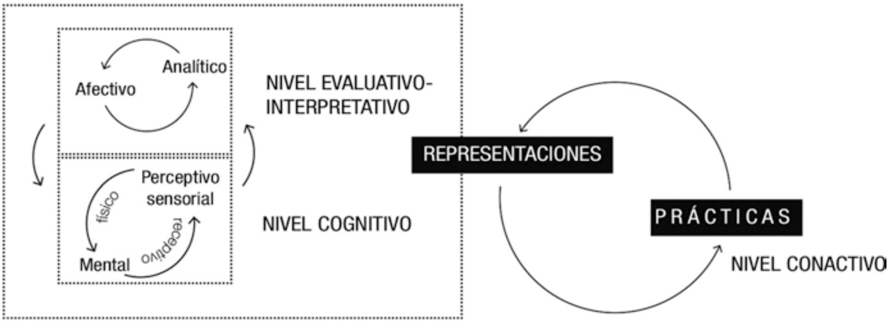


Fig. 6.1 Pair of forces, city, and nature. (Source: Vallarino, 2019)

As of the study of desires in human life, alternating innate searches and possible influences of external forces, research is carried out on how individuals interact with the city and nature, the ways of inhabiting, and the types of derived spaces. An approach is made to the question of the landscape from the social sciences, emphasizing actors and meanings. The landscape is then taken as an analyzer to reflect around the city/nature relationship.

TAM was developed as a theory of analysis and interpretation of reality. It aims at a dynamic balance of moments, articulating the physical, rational, and affective planes. The articulation between the lever arms of the moments is the human condition, as a trilogy (individual/species/social being). As a species, it is important to fully recover the value of one's own body (e.g., multisensory apprehensions). As individuals, life stories are significant. On the other hand, in the consideration of man as a social being, imaginaria come into play, enabling the consideration of a time measurement unit that spans several generations, involving memory and collective identity. For landscape studies, it is necessary to take the human being as a whole, encompassing the three axes of the trilogy. From TAM derives the notion of landscape that guides us: an articulation between human practices and representations associated with nature.

These notions influence the theoretical and methodological developments of our works, which have integrality as one of their foundations. This results in kinds of spaces that should be interconnected, different levels of interaction between man and the environment: the sensory-perceptual, the cognitive mental, the analytical and the affective, and, in the culmination, the level of representations and practices (Fig. 6.2). It aims at human fulfillment, for which the being as a circumstance (as in the Spanish verb "estar") must be complemented with being as essence (the verb "ser"), the necessary and sufficient conditions must be fulfilled, the former making man a biological being, and the latter covering interpersonal and suprapersonal aspects. If this is not achieved, a void is created which is also reflected in relationships with the environment.



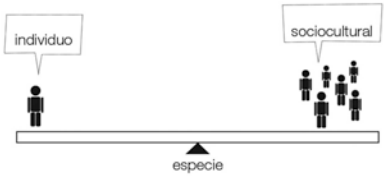


Fig. 6.2 Species of spaces. (Vallarino, 2019)

6.3 Heterodox Decalogue

To bring to fruition the understanding of the city as an ecosystem and the incorporation of the landscape as a tool to apprehend the multifunctionality and articulation of the natural and social aspects of ecosystem services, when designing with green infrastructures, we must focus on a comprehensive understanding of nature. This implies attending to the values associated with nature that, generally, within Lynch's categories of values, would be illusory, weak, or relegated. That is why I am inspired by the foundations of Professor Cravotto's Heterodox Decalogue, recycling them. It is concerned with the opportunities for participation of all individuals, for which it resorts to the usefulness of utopia understood as «the correct direction of social progress» determined by a starting point, the current situation, and a point of arrival, «which although unattainable in practice, ensures the correct direction» (Cravotto, 1990). The skills and competence of landscape design researchers are essential to be successful in this regard (APEC and Deloitte, 2010), which is why the articulation between the Academy and political power (ANDES, 2007) is a key strategy for urban landscape design, planning, and management.

I will then develop an outline to guide the understanding of the city as an ecosystem based on the articulation of the cardinal principles of the complexity paradigm with theoretical, thematic-disciplinary, tactical, and strategic criteria. In this way, the discourse is organized based on a helical structure that allows us to analyze different leitmotifs from different perspectives.

In relation to the dialogic principle, this chapter will address the overcoming of particular antagonisms with superior constructions associated with the notion of the

principles of the complexity paradigm			HETERODOX DECALOGUE
dialogic	THEORETICAL	man	human codition
	THEORETICAL-METHODOLOGICAL	thematic-disciplinary	art/natural sciences / human and social sciences
	METHODOLOGICAL	tactical	ICT and lived experiences
		strategic	knowledge, collective consciousness and third landscape
recursive	THEORETICAL	nature	practices and representations
	THEORETICAL-METHODOLOGICAL	thematic-disciplinary	conceptual and methodological
	METHODOLOGICAL	tactical	to focus /to take distance
		strategic	means and end
holographic	THEORETICAL	city	urban nature and green infraestructures
	THEORETICAL-METHODOLOGICAL	thematic-disciplinary	multi, inter and transdiscipline
	METHODOLOGICAL	tactical	integrality
		strategic	collaborative work

Fig. 6.3 Heterodox decalogue, scheme. (own elaboration, specific for this article)

human condition, the relationship between art/natural science/human and social sciences, the articulation between ICT and lived experiences (tactical aspects), and, finally, the strategic guideline of linking knowledge, collective consciousness, and the Third Landscape.

Inscribed in the recursive principle, we will propose derivations of the notion of landscape already outlined – the loops between practices and representations and between the theoretical and the methodological – as well as tactical (to focus and to take distance) and strategic issues (loop between means and ends).

Finally, the belonging of the whole to the parts and of the parts to the whole, typical of the holographic principle, will be analyzed, based on notions associated with urban nature and green infrastructures, thematic-disciplinary issues (the multi-, inter-, and transdiscipline), tactics, and strategies (integrality and collaborative work) (Fig. 6.3).

6.3.1 Dialogic Principle

Human Condition

It is essential to start from the conception of man as a trilogy which associates the condition of an individual, the belonging to a species and the social being. This association is closely linked to the triune brain that links drive, reason, and affectivity (Morin, 1977) and where the balance, beyond protagonisms that alternate temporarily, is in the whole (Fig. 6.4).

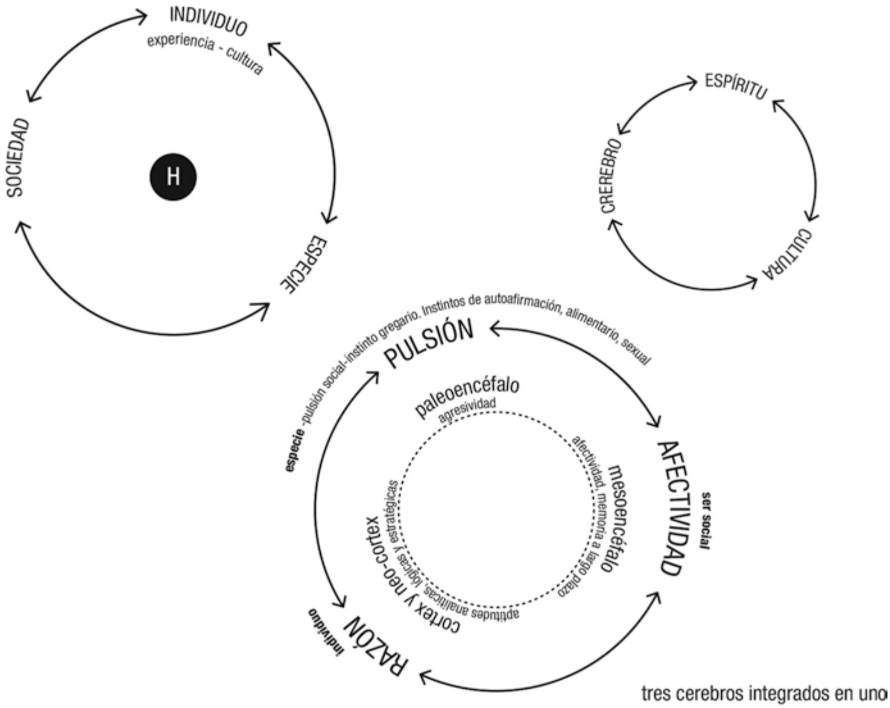


Fig. 6.4 Human condition, triune brain. (Vallarino, 2019)

It is thus that I consider it essential, for a comprehensive landscape design, to take into account both the position of man as an integral part of nature, as a species, as well as his situation outside of it, from a cultural point of view.

Art/Natural Sciences/Human and Social Sciences

These disciplinary crossings, including an artistic profile, enable us to deal with issues using an approach that contributes to the understanding of reality from a higher perspective.

Our line of work, "artistic anatomy of plants," which contains several projects and activities that intersect with other lines of work (Fig. 6.5), is illustrative in this regard. It articulates objective aspects (morphological and physiological qualities of the plant), typical of the natural sciences, with subjective aspects (practices, representations, and meanings), which in the human and social sciences are considered in qualitative approaches associated with values. The rational is linked with the emotional, finally combining the "creative" nature (*natura naturans*) with the "created" nature (*natura naturata*).

Fig. 6.5 Project "artistic anatomy of plants": activities and products. (Photos by Vallarino & Olguin; SMA FADU Udelar, 2019)

ICT and Lived Experiences

Technology allows us, on the one hand, to go beyond our basic possibilities as a species (e.g., complementing the aptitudes of our body in terms of its strength or the qualities of our senses), but, on the other hand, it distances us from nature by acting as an intermediary between our body and the environment that surrounds us. That is why it is strategic, in educational policies and in public outreach and awareness strategies in general, to promote the articulation of direct contact with nature (e.g., in recreational or didactic outings in the open air) and the use of the body as an instrument of experimentation (e.g., with manual work such as freehand drawing), thus involving the emotional. On the other hand, these aspects are complemented with the use of ICT, enriching the experiential (the « estar»), with transcendental aspects, which make the being (the «ser»), going beyond the particular case.

In our activities we propose as a learning objective, beyond the incorporation of knowledge, to aim at the incorporation of research methodologies in practice, encouraging observation and integrating ways of building knowledge, as well as ways of thinking and creating. In the case of the school workshops of the OMBÚes project (Fig. 6.6), we worked with ICT on the one hand and with natural drawing on the other. We sought to enhance lived experiences by aiming to connect the inner being with the outer being: «drawing means making the inside and outside of our bodies proportionally dependent. Drawing is the record of our movements (between balance and imbalance) produced by adjusting this relationship of proportion between the internal and the external. Gestures and thoughts record these transitions, these glides that produce a pulsation that, no matter how little we devote to it, is irregular and continuous. What we call drawing is the record of this pulsation» (Brisson, 2019, p. 17).

The urban landscape reality requires considering public open spaces in an intimate relationship with private open spaces from a dialogic perspective that transcends the physical, paying attention to the intangible, the symbolic, communications in general, and ICT in particular as a fundamental variable. We can appreciate it in the reflections that were produced already in 2009 regarding the appropriations and absences of the urban open space system (Tângari et al., 2009a). Specifically, as Souza expresses it, the relations between space, circulation, and perceived messages are essential components of urban life and the spatial organization of the city; changes in the city depend on and are, at the same time, the result of changes in the modes of communication between individuals (Souza, 2009, p. 111).

Technology is considered to affect social practices and political relations (Rodríguez Gustá, 2008). OMBÚes uses ICT to develop methodologies and innovative tools that enhance educational processes, expand the territorial and social scope of knowledge, and integrate diverse areas such as rural and urban. It thus aims to

Fig. 6.6 OMBÚes Project, school workshop School n° 5, Fray Bentos. (The teachers of those children were Johana Miñán and Carolina Angenscheidt, 2018)

contribute “to universal access to education, equality in instruction, the exercise of quality teaching and learning” (UNESCO. Building Knowledge Societies, 2017). ICTs enable a shared space where different approaches to nature complement each other and where socio-territorial integration is strengthened at the national level.

Knowledge, Collective Consciousness, and Third Landscape

Nature, through the landscape, acts as a symbol that gives meaning to society (Berque, 1999, pp. 76–77). In turn, vegetation is a privileged element in this symbolic operation. In particular, the ombúes (*Phytolacca dioica*) for their emblematic character from a landscape point of view – since they are an indigenous species of the humid pampas, for their size and majesty, for their longevity, for their medicinal properties, for their dioecious character, and for their morphology and herbaceous consistency, due to their symbolic values – are special instruments of sensitization and awareness. Focusing on an element that transcends disciplinary, spatial, temporal, and social boundaries is of particular importance as a tool for social integration.

In other words, the association between vehicles for knowledge of reality and sources of inspiration is strategic. Making a parallel with the idea of “Third Landscape,” knowledge is considered as “a shared fragment of a collective consciousness” (Clément, 2007) and as an instrument for diversity and integration.

6.3.2 Recursive Principle

Practices and Representations

Nature exercises a strong power of reference in our western societies. This is due to the fact that its meaning is appropriable by all, given its cosmic character, and in addition to the fact that each one experiences in his own body the fact of being part of nature (Berque, 1999, pp. 76–77).

From the expansion of the notion of landscape presented in the conceptual framework derives the complementary opposition between landscape practices and representations. The former includes physical activities, ways of living, management of outdoor spaces, and exploitation of natural resources or the exercise of a profession applied to space planning (architecture, urban planning, landscape architecture). The latter comprises knowledge, mental representations (ideas and imaginaries), and artistic ones. These continually condition each other, contributing to the construction of our identity.

Material nature and natural myths and symbols (Luginbühl, 2012) support social landscape representations. In turn, nature, real and represented, conditions the construction of the human habitat (Vallarino, 2016). Nature is the result and origin, then, of a collective construction. Vegetation in general and trees in particular are paradigmatic natural components for their evocative capacity. Their complex physiology favors metaphorical or symbolic analogies (Dumas, 2002, p. 235). Their morphology and physiology influence how they are perceived and valued. Likewise, given that the life cycle of tree specimens is generally greater than that of individuals, the values associated with them involve collective memory, social imaginariums, and the identity of nations. Through these values, it is possible to analyze the complex relationships between nature and human beings. All this results in representations and landscape practices associated with nature.

Conceptual and Methodological

Applying a recursive process between theoretical notions and methodological practices mutually enriches them. This was done with TAM, which advanced in successive approximations based on an overlapping structure. Likewise, when opting for the «case study» method – either instrumental or intrinsic – allows us to show the evolutionary and complex nature of social phenomena (Collerette, 2004). In the case of the OMBÚes project, what is studied are the qualities of *Phytolacca dioica* and its extrapolation to landscape values. These values are expressed in practices, knowledge, and representations associated with the humid pampas. They include literary, pictorial, photographic, and musical works. They encompass social, landscape, urban, and architectural practices. They also favor the birth of myths, legends, and anecdotes associated with the species, isolated specimens, and groups of ombúes. This knowledge serves as the basis for teaching and extension practices, as well as for dissemination activities and outreach products.

To Focus/To Take Distance

The OMBÚes project already manifests this tactic in its essence and graphic form. In Spanish (OMBÚes = OMBÚ + es), it tries to imply the plural and the verb to be. It brings together different interests in a triple sense: a quantitative game (from individuals to groups of ombúes), a qualitative game (the species and plant individuals), and a relationship game, emphasizing meanings. The verb "to be" suggests "the ombú is," "nature is," and "man is."

In other words, putting focus or distancing oneself from the themes allows different spatial scales as well as various optical ones, such as taking into account contemplative and utilitarian nature, ultimately enabling a sensitive approach to nature.

Means and End

Representative in this sense is the «instrumental case study method», where the case becomes of secondary interest (Collerette, 2004, p. 93).

TAM was based on the study of a typical case, the coastal avenue – rambla – in the city of Montevideo, Uruguay. Given its paradigmatic nature, it was taken as an instrument to test the theory applied to the city/nature relationship, aiming both at its particular study and at extracting generalizable reflections for other scenarios.

This strategy was also followed in the OMBÚes project, so that knowledge is an instrument of extension activities, the goal of the research project, and the object of teaching activities. The role of the ombú/ombúes/*Phytolacca dioica* is dual in itself and in relation to its functional context.

Finally, in the case of university education in particular or of education, awareness, dissemination, or public awareness in general, students and citizens are an end and a means: they play a double role as consumers and creators of culture. This is the case, in particular, with the collaborative and research-dissemination activities of the OMBÚes project, as it is with the collaborative processes in general.

6.3.3 Holographic Principle

Urban Nature and Green Infrastructures

City and nature mutually determine each other in a dynamic balance that includes multiple dimensions which involve the notions of public space, open spaces and green spaces (Soares Macedo, 2009). Attending to the «thematic porosity that transcends disciplinary formatting» (Tângari et al., 2009b) allows us to apprehend the urban landscape complexity. This implies being based on a materiality, including a systemic approach, to later transcend it by attending both to nature in the city and to the city in nature, involving the artialized nature in the city. The vision of this complexity is fundamental in approaching design and landscape management based on green infrastructures.

In political strategies, it is key to pay attention to illusory values, the weak and the relegated ones. In this sense, it is necessary to attend to the fact that the neglected sectors can be so for various reasons. A lack of economic resources can lead to not being able to satisfy basic needs (food, health, housing) or to not meeting sufficient conditions (education, recreation, social life, personal aspirations). Thus, depending on the context, the relationship with nature may become lively and direct but not as a matter of choice. There is no distance that allows valuation. But civility can also be a problem because it involves establishing a distance, moving away from spontaneous relationships (on a human and environmental level), uprooting the being (Spengler, 1965). Thus, when basic needs have been met, direct relationships with nature – with that of one's own essence and with that of the environment – can be lost due to a conflict between interpersonal, suprapersonal, and intrapersonal aspects. A vacuum is generated that does not allow the complete fulfillment of the human being, which is also reflected in relationships with the environment. So, while some are slaves of nature (because they cannot reach a sufficient level of civilization), others are slaves of civilization (and are condemned to be unable to enjoy nature) (Vallarino, 2019). The emphasis on the quality of urban life in relation to the experience of public spaces is fundamental. It is the common thread that guides us at FADU when counseling in relation to public spaces.

Finally, nowadays it is necessary to attend to the essence of urban nature and take into account the generalized urban and techno-nature («nature hybridized by technology») (Le Dantec, 2002).

Multi-, Inter-, and Transdiscipline

We intend to keep the problem of knowledge of nature associated with that of the nature of knowledge (Morin, 1977), taking into account the multidisciplinary nature of the landscape topic. A multi-, inter-, and transdisciplinary approach allows the issues of each discipline to be addressed, those of the notion and those that go beyond one and the other. In this way, we build a round-trip between the global and the local, rescuing popular knowledge and disseminating scientific knowledge.

Integrality

Integrality must attend to the subject, the instrument, and the object. Romano first considers the subject as an integral being (2011), which would imply the human trilogy that we saw at the beginning. Secondly, Romano refers to the educator and points to the link between university functions (teaching-research-extension). Finally, he focuses on the object of knowledge, betting on the disciplinary articulation, which we have just developed in the previous item. The integrated approach, attending to the different topics, actors, times, resources, and territories, was already a key objective for the sustainable urban management of European cities at the beginning of the twenty-first century (Beaupuy, 2008).

Collaborative Work

OMBÚes takes advantage of ICTs to expand the scope of the project by developing a collaborative strategy. In particular, given that ICTs have popularized the use of maps, we use collaborative cartography to create a community that contributes to collective knowledge. Cartography in general is a social process of territorialization by which society, through technical and symbolic operations, marks, appropriates, and gives meaning to its living spaces (Besse, 2001, pp. 126–145). In the case of OMBÚes, cartography is both an object and a tool, articulating the role it plays for landscape architects (understanding landscapes) with the one it plays for artists (questioning the reality of the world in which we live).

Thus, the articulation of face-to-face workshops, cartography, ICT, and collaborative work fosters the appropriation of results, helping to create a collective conscience and strengthen the feeling of identity.

6.4 Provisional Conclusion

The heterodox decalogue aimed to separate in order to analyze, although we now have to bring everything together again, relating to synthesizing and making more complex, according to Morin (1977), beyond the fact that the porosities between sentences have already been glimpsed throughout the dissertation, outlining a complex unit. We promote attending to the relationship of the subject with its cultural, social, and historical environment; we aim at integrality and the need for moments, the product of dual forces and distances, to which TAM refers.

It is unavoidable that we pay attention to historical circumstances to understand the practices and ways of forging concepts of each culture. In history, slowdowns and accelerations continually occur (Luginbühl, 1992, p. 12), which are the different values of the pendulum's acceleration after its arrival at each pole and where the extremes acquire their value as components of an opposition relationship and complementarity.

This is the case of life and death in general and the birth and death of landscapes in particular.

This topic was the subject of a colloquium in Lyon in 1981 that resulted in a collective work, Mort du paysage? (Dadognet, 1982).

Alain Roger took up the theme again in 1997 (Court traité du paysage) aiming to renew the gaze – through his theoretical tool, artialization in situ/in visu – to overcome the landscape crisis of the moment. For him, art can transform ugliness by resignifying it, poetizing it, and developing a new system of values.

For his part, in 2002, Le Dantec, while rescuing Roger's need to differentiate landscape and environment, qualifies Roger's position as optimistic, considering that it is necessary to go further to reconsider the need for a new alliance between man and nature. It proposes to overcome the simplistic positions that are a product of the generalized urban and of techno-nature, reconciling ecological knowledge and sensibilities with the contemporary landscape and articulating the art of gardens with landscape architecture. Faced with trivialization and standardization, he appeals to the unpredictable, the spontaneous, and complex (Le Dantec, 2002).

In 2017, the Observatori del Paisatge de Catalunya organized a conference based on the deurbanization project of La Pletera (Catalunya, Spain), which ended in a publication, ((Des)fer paisatges, 2018). It proposed to undo a landscape that has been decontextualized and is not socially valued in order to remake it, taking into account its resignification and, therefore, the citizens' quality of life, linking artistic and environmental conditions (Sala i Marti, 2018).

This provisional conclusion intends, just like these activities and products, around the life and death of landscapes and, like TAM, to open doors to contribute to the continuous cycle of collective construction, starting from the idea of scientific knowledge as fundamental engine of humanity. TAM proclaims articulation as a fundamental instrument: of scales – physical, temporal (e.g., between political and academic times), and conceptual – of disciplines, of interests and values, and of rights and responsibilities. All these articulations pave the way for the success of landscape planning with green infrastructures.

TAM proclaims the articulation of force, the being as circumstance (the «estar» which enables knowledge acquisition and the use of specific resources), with the distance, the being as essence (the «ser», which allows a critical stance and valuing the former), as the key to all sustainability. The «estar» and the «ser» also enable the local – global articulation and the rupture of short-term temporal scales (articulating the times of man as an individual with those of man as a species and social being) – requirements of a collaborative collective construction.

As early as 1995, it was argued that the social emergence of the landscape was related to the ecological-environmental wave that shook consumer society. This has resulted in the landscape becoming a political issue: its analysis is posed both in terms of power and knowledge (Bertrand, 1995, p. 89). The articulation between the Academy and the political power helps us to attend to the real and disciplinary complexity of the factors involved in the design, planning, and urban landscape management with green infrastructures. It is important to support the development of mediating structures between research, the economy, and society and to promote inter-institutional intermodal frameworks (public/private, academia/business, KIBS) (ANDES, 2007). On the one hand, scientific skills, project management, and teamwork skills are essential, as well as personal skills of creativity, openness, motivation, and adaptability (APEC and Deloitte, 2010) associated with academic work in landscape design. On the other hand, the notion of quality, "understood as the characteristics or attributes of a being or of a thing to which a given actor gives importance" (Brédif, 2008), is a fundamental operator of sustainability. Quality must be something more than the opposite of quantity, but it also has to overcome the contradiction that the indicators established by official bodies, to define sustainable development, for example, seek to legitimize themselves in scientific measurement (Brédif, 2008). We must attend to the notion of quality, as well as the notion of natural, as something that is not necessarily synonymous with value, but rather articulates something essential with a value judgment. This leads us to go beyond what could be "meeting the needs of a client" (business leitmotif), interpreting requirements, and anticipating citizens' expectations. That is why it is key to attend to the intersubjectivity of the landscape, integrating the subjectivity of local actors in the design and planning in order to consider the values associated with nature and achieve their integral understanding (combining the intelligible with the sensitive, the analysis, and invention of landscape, according to Le Dantec (2006, pp. 80–81)). These articulations are key to contribute to the promotion of self-sufficient land use, the stimulation of social and natural processes associated with ecosystem services, and the awareness and sensitization of the ecosystem importance of the city.

Life cycles include births and deaths (e.g., of landscapes), construction of new knowledge and ventures, new creations, and implementation of environmental, landscape, and urban policy guidelines and strategies. Different life cycles intersect: those of individuals and those of societies, academic times, business times, and times of power and political strategies. Success in the integral apprehension of nature, and therefore in the adequate incorporation of green infrastructures in the design and landscape planning, depends on the good articulation between these cycles, relying on knowledge and collective constructions in the framework of collaborative work strategies.

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Chapter 7
Green Infrastructure as Urban Melody: The Integration of Landscape Principles into Green Infrastructure Planning and Design in China and the UK

Ying Li and Ian Mell

Abstract The concept of green infrastructure has gained political momentum globally and, therefore, has been rapidly introduced into planning theory, policy, and practice in the USA and Europe. Yet, it does not have a single widely recognised or accepted definition and has been adopted fluidly by various disciplines. In this chapter, discussions of green infrastructure focus on landscape architecture interpretations in both planning and design at various scales in China and the UK. The aim of this chapter is to further understand the social, economic, and ecological values of urban green infrastructure within diverse development contexts and use China as a key focus of this discussion. However, an understanding of the legacy of 'green infrastructure' planning based on UK and North American conceptualisations is critical to appreciating the nuance of application in China. The process of urbanisation has escalated rapidly in China since it opened up economically from the late 1970s onward. A significant part of this was the adoption of Western approaches to the design, building, and management of green infrastructure in the urban areas. Consequently, there has been an increase in public space, parks, riverside walks, and squares built within Chinese cities that reflect a global understanding of landscape rather than classical Chinese interpretations. The clash of styles provides an interesting lens through which to review the spatial development of green infrastructure examining how the application of Western ideas is applied in a Chinese context. This reflects on the plan-making and design of green infrastructure as well as its contribution to people's daily life, health, and well-being and the harmony

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between nature, the city, and people. The chapter concludes that green infrastructure plays a central role in promoting an *urban melody* through the design and provision of connected and high-quality green space. By creating a multi-scaled and multi-functional set of landscape resources, green infrastructure can be considered to orchestrate the symphony between nature and city.

Keywords Landscape principles · Green infrastructure · Urban melody · China and UK

7.1 Introduction

Across the world, there is significant variation in how 'landscape' in its broadest sense has been aligned with urban development. Although we can identify an ecological structure for most urban development, i.e. being located on rivers, coastlines, or near fertile land, there is much greater diversity in terms of how nature is incorporated into urban footprints. Consequently, the value of nature per se, and landscape functionality specifically, now commonly defined as 'green infrastructure' is fluid between locations within a city, within a country, and globally. Such variety is becoming increasingly problematic as urban areas are facing significant climatic and socio-economic stresses. Our understanding of air pollution, flooding, poor health, and economic stagnation is related to the composition of our urban areas and the interplay between people, politics, and place. Many cities are addressing these issues head-on via 'sustainability' and 'resilience' policies that focus on the management of ecological resources. Moreover, an appreciation of the nuance of these terms is often lacking in policy (Meerow & Newell, 2017). However, forward-thinking praxis remains the exception rather than the norm, meaning that there is a critical need to reflect on how we understand the value, function, and utility of green infrastructure and where examples of best practice can be shared to improve the liveability of these places.

As urban areas continue to expand, divergent approaches have been taken to how ecological design via the practices of landscape architects has been employed (cf. Fábos, 2004; McHarg, 1969). There is a wealth of literature examining the role of landscape in different locations reflecting on the cultural appreciation of nature, its value in urban development, specific design principles, and the changes (or indeed transference) of this knowledge as cities continue to grow (Mell, 2016). It is within this academic/practice space that we discuss the role of landscape and landscape architecture within the wider framing of green infrastructure. As a consequence, green infrastructure, as a term, is not used extensively within this chapter. Alternatively, we discuss landscape as a core idea linking the conceptual underpinning of green infrastructure with the design and application inherent in landscape architecture.

Two examples of this process will be used to structure the arguments made in this chapter. The historical development and utilisation of landscape in the UK and contemporary applications in a Chinese context will be debated to illustrate the variability in approach to landscape planning and its consequent impacts on development.

China and the UK are discussed as both have a legacy of integrating landscape principles into urban planning via small-, medium-, and large-scale features, such as gardens or Green Belts (Li et al., 2005; Hall, 2002). The application of this legacy has though been delivered in very different ways. The divergence in practice and the transition of approaches will be discussed as a key part of this process. The following thus aims to trace the lineage of landscape within planning, and its value to green infrastructure thinking in contemporary planning, the convergence of practice, and identify the potential direction of landscape architecture in the future.

7.2 Philosophy of Landscape Planning in China and the UK

Due to variations in topography, landform, and urban composition, the perception of the environment in Europe and China are distinct (Tuan, 1974 p.31). This leads to a visible difference in the conceptualisation and application of landscape, as an idea and in planning practice, in China and Europe. A further factor influencing the structure of landscape design in China and Europe is the underlying philosophy of garden and park design (Pregill & Volkman, 1999: 35). For example, in Europe the philosophy of living harmoniously with nature developed much later than in China, as Tuan (1974:31) argued:

> Nature did not enjoy wide appeal among well-to-do Europeans until late in the eighteenth and early in the nineteenth century when more members of the leisured class took it up. Observing nature became a fashionable pastime, the thing to do.

Moreover, it is common to see city parks designed to reflect rural landscape in UK cities utilising swaths of open lawn supplemented with groups of trees and waterways or water bodies (Lawrence, 2008). In China, there is a predominance of smaller and more ornate ‘gardens’ that are structured around *water*, *buildings*, *rock*, and *people*, the four core elements, developed to be intimate rather than expansive. Representations of nature in China and Britain are therefore divergent and reflect the ongoing legacy of historical appreciations of landscape features (and to a lesser extent function). However, there is also a line of argument stating that the composition and spiritual and functional meaning of landscape in the UK and China are comparable if they are viewed via a lens of the Sharrawaggi style of composition in Chinese landscape architecture and Picturesque style as the presentation of nature in the English landscape.

7.3 Sharrawaggi: Nature in Classical Chinese Garden

China’s physiographic meaning bears little resemblance to that of Europe. In western and northern Europe, the predominant landscape is historically one of farmlands with a rolling topography. China, by contrast, lacks a rolling topography and, except in a minority of places, has little to no ‘parkland’ scenery of open grassland dotted with wood lots (Tuan, 1974). Alternatively, Taoism has influenced Chinese landscape painting and the subsequent philosophy of garden design (Keswick et al., 1986). Taoism advocates the harmony of man and nature and holds a significant role impacting upon the built environment in China (MAK, 2009). Chinese parks and gardens, in contrast, have been influenced by Shan Shui (Chinese: 山水; Translation: mountain and water) (Moffett, 2003) and use the concept of Shan Shui Hua (Chinese: 山水画; Translation: the painting of mountain and water), even though they are artificial (Mitrasinovic, 2006: 43). There is unfortunately little recorded material of the art and or visual style of this period. In a Western (i.e. European) context, the first description of the Chinese garden is Sharawadgi (also Sharawaggi) by Sir William Temple (1628–1699). In his book *Upon the Gardens of Epicurus* (Temple, 1908), he described the design of classical Chinese garden as 'without any order of disposition of parts,' whilst Keswick (1986:7) described Classical Chinese Garden as:

> …confusing and dense, dominated by huge rock-piles and a great number of buildings all squeezed into innumerable, often very small spaces.

Her description of the Chinese garden as 'cosmic diagrams, revealing a profound and ancient view of the world and man's place in it,' offers a common framing that identifies the composition of classical Chinese gardens to include rock, water feature, vegetation, pavement, and architecture. The concept of the composition of views in a garden are usually based on 'Shan (mountain)-Shui(water)' painting, and the design narrative is highly connected with Chinese poetry and music. This design philosophy is frequently a representation of the garden owner's perception of nature and its link with the wider cosmos or spiritual world. For example, The Humble Administrator's Garden (Chinese: 拙政园) in Suzhou is the largest classical garden in the city and is considered by some to be the finest garden in all of southern China. The design concept of the landscape is based on Chinese poetry, the layout of the garden also followed the principle of Chinese painting, and the garden presents the owner's wish for a utopian society. This garden shows the typical character of Chinese Garden that contains Life Conception (Chinese: 生境), Picturesque Conception (Chinese:画境), and Artistic Conception Chinese:意境). The composition of the Humble Administrator's Garden is also considered to have created a movable panorama of landscape views, which have been compared with the composition of music and the creation of its overarching melody or motif (Sun & Zong, 1987).

7.4 Picturesque: Nature in British Landscape

Sir Geoffrey Jellicoe (1900–1996), in his book *The Landscape of Man*, describes how the concept of 'nature' from Chinese Landscape design influenced the philosophy and design style of English landscapes then spread in Europe in the early eighteenth century. Jellicoe and Jellicoe (1995: 233) noted that:

> The school was indigenous to England, springing from a relation to nature that had always been latent but only now emerged from beneath the fashionable Italian and French classical overlays. The movement was literary, spontaneous, and seems first to have been fired to take physical form by Sir William Temple's description of the Chinese School, to which it was sympathetic. Nature was no longer subservient to man, but a friendly and equal partner which could provide inexhaustible interest, refreshment and moral uplift; irregularity rather than regularity was proclaimed as the objective of landscape design.

Jellicoe's appreciation of the influence of Chinese landscape design encouraged the birth of a new style presented as The English School: Picturesque. Assessments of the Picturesque illustrate links with William Temple's description of classical Chinese Garden, i.e. Sharrawaiggi, that a certain irregularity in style in garden design is visible in both (Kuitert, 2013). The Picturesque approach inherited the Romantic spirit of the eighteenth century, and from this point onwards, Picturesque became popular in landscape design replacing the regularity of the symmetrical, geometrical, and formal landscape styles of the seventeenth century popular in mainland Europe. It also concentrated on the representation of an idealised perception of nature in the landscape. William Kent (1685–1748) was the pioneer of the implementation of this style into garden design practice drawing inspiration of what 'nature' was, and should be, from the landscape paintings by Claud Lorrain and Nicolas Poussin. Consequently, the visual composition of the Picturesque English landscape garden is usually characterised by the idyllic and pastoral, including gently rolling lawns set against groves of trees, curved paths, water features, and Picturesque architectural structures, i.e. bridges, bandstand, pagoda, classical temples, and Gothic ruins.

During the development of the Picturesque in the English School, Lancelot 'Capability' Brown (1716–1783) and Humphry Repton (1752–1818) sat at the center stage. Brown worked under Kent providing him with opportunities to assist the garden design including those for Blenheim Palace Garden in Oxfordshire, Chatsworth Garden in Derbyshire, and Moor Park, Hertfordshire. Repton regarded as the successor to Capability Brown is considered the last great English landscape designer of the eighteenth century and helped pave the way for the eclectic styles of the nineteenth century. In addition to the influence of romanticism and Chinese Sharrawaggi, the social and political changes of the eighteenth century also shaped landscape planning in the UK. The increasing middle class in England saw the implementation of the Picturesque in private landscape and garden design as a presentation of the social status.

To summarise, in terms of the approaches taken to integrate nature into small- and medium-scale landscape and garden design, and in the visualisation of the completed work, the English Picturesque could be considered to centre on ecologically focussed design compared with the development of classical Chinese Gardens due to the involvement of the large swaths of green space to animate the pastoral landscape. In contrast, the use of stone mountains is the most distinctive visual motif of Chinese Garden used to suggest silence abstraction in the garden, rather than an evolving natural visage, and it is the representation of the stone mountain in the natural world. Stone hills are therefore used frequently to enhance the visual appreciation and ornamentation of a garden rather than its ecological diversity or interactivity. Although different in approach, as noted above, there is a complementarity in approach between historical approaches to landscape in both China and the UK, which will be discussed in a contemporary context in the following sections.

7.5 From Picturesque to Garden City Movement: Nature in the English Town Planning

Although the Picturesque flourished in Britain, it requires a contextualisation within the social environment of the Victorian Era (1837–1901). This was the peak of the industrial revolution when culture, art, science, and economics expanded and Britain occupied 70% of the world's economy. As discussed above, the rapid growth of the middle class placed an increasing value on the rural scenery of England, with the view that being close to nature was an escape from urban sophistication of Victorian life (Jellicoe & Jellicoe, 1995: 276). Nature, and the ability to interact with it as well as own it, was therefore seen as a representation of social status. This in turn encouraged a transaction from the Picturesque concept for garden design to what we know as town and landscape planning.

In the mid-eighteenth century, Britain's population was equally distributed between urban and rural. With the publication of *To-Morrow: A Peaceful Path to Real Reform* (1898), Sir Ebenezer Howard introduced the Garden City concept that explicitly incorporated landscape architecture ideals with his social, economic, and regional planning concepts to promote his view of a utopian city, where people would live harmoniously with nature. Howard's approach was to integrate town and country, built form and rurality, via the introduction of 'landscape' into planning. This drew on the concept of dominant landscape and garden design principles of creating a transition from a beautiful foreground through a picturesque middle ground to a sublime background (Turner, 1996). The world's first Garden City was Letchworth Garden City in Hertfordshire and was followed by the construction of Welwyn Garden City. Howard's mandate directly influenced future town planning, the New Towns movement in the UK, and to a certain extent the promotion of sustainable, walkable, and liveable places (Hall, 2002).

The Picturesque and Garden City movement also influenced other countries. Urban landscape planning evolved from the impregnation of the classical principles of town-planning as employed by Howard and others (Fishman, 1982). For example, in North America, Frederick Law Olmsted adapted this concept of landscape planning for urban design, by planning park systems utilising the English Picturesque style in his landscape design. His approach was in 'Notes on the Plan of Franklin Park and Related Matters' (Boston, Department of Parks, 1886: 107):

> Olmsted used the style of the Beautiful-or as he usually called it, the Pastoral – to create a sense of the peacefulness of nature and to soothe and restore the spirit. The Pastoral style was the basic model of his park designs, which he intended to serve as the setting for 'unconscious or indirect recreation'. The chief purpose of a park, he taught, was 'an effect

on the human organism by an action of what it presents to view, which action, like that of music, is of a kind goes back of thought, and cannot be fully given the form of words.

The Garden City movement was also considered as a method of urban planning in which self-contained communities surrounded by 'greenbelts' containing proportionate areas of residences, industry, and agriculture could be created. The development of suburbs in North America, although influenced by the Garden City concept, shows an alternative and more spatially diverse approach to Garden City intervention. Examples of this include Forest Hills Gardens designed by F. L. Olmsted Jr. in 1909, Radburn in New Jersey, and the Suburban Resettlement Program towns of the 1930s, i.e. Greenbelt (Maryland), Greenhills (Ohio), Greenbrook (New Jersey), and Greendale (Wisconsin).

Contemporary approaches to landscape and urban planning retain the ethos of Howard's work in the UK and illustrate the influence of Olmstead in North America. The rise of sustainable communities and the promotion of resilience to climatic and socio-economic change are evident in planning activities that support the ongoing legacy of both. However, the rise of 'sustainability' as a catch-all forward-looking policy and practice may undermine the values installed in development by Howard and Olmsted (Eisenman, 2013). How planners, politicians, and developers utilise the landscape draws on the notions of integrating town and country suggests an ongoing engagement with these ideas. Unfortunately, the ways in which they are presented and the critical understanding identifying balance between landscape capacity and human needs are often lost (Mell, 2016). Consequently, the value of landscape planning can be undermined when compared to economic development arguments. This reflects the critique of planning by Jellicoe when he noted that nature is constantly being disturbed by humans with little respect for its value as a complex set of ecological, economic, or socio-cultural systems. It is within the space between Jellicoe's position and that of Howard, Olmstead, and McHarg (1969), and more recently Sinnett et al. (2015), Austin (2014) and importantly Benedict and McMahon (2006), that the ongoing contestation of landscape and urban is debated.

7.6 Chinese Urbanization, Economic Reform 1978 and Landscape Concept

From a Chinese perspective, a series of actions are seen as being critical to the use and understanding of landscape. In eighteenth-century China, the Qian Long (1711–1799) Emperor established a Closed-Door Policy toward the Western World to limit the spread of Christianity, which left Guangzhou as the only trading port in China. This policy resulted in China isolating itself from the world and internalising its cultural, economic, and scientific development (Keller & Shiue, 2020). During this period, the concept of landscape and urban planning was developed based on the classical Chinese garden design theory (Gu et al., 2017), and thus, the balance between the provision of human needs and nature within urban areas was potentially compromised, as classical gardens were private rather than public open spaces. The programme of internal reflection was embedded within Chinese law in 1949 when Mao Zedong proclaimed the formation of the People's Republic of China (PRC). The promotion of collectivisation and the support of an agrarian society limited the urbanisation process, and only post 1978-reform did the country's urban areas start to expand (Gu et al., 2017). Since China's opening up, the country's society has changed drastically with industrialisation and urbanisation driving its economic growth, for example, urbanisation increased from 17.92% in 1978 to 58.52% in 2017 (Xiao et al., 2018).

However, despite China's rapid growth, there has been a lack of reflection in policy and practice of landscape. From 1978 onwards, landscape has been allocated a secondary priority in policy, with more limited landscape architecture education equivalent to the UK or North America in China; what practice is taught focusses on Garden design and history (Li et al., 2005). From 2011 onwards a change in government emphasis significantly altered this dynamic when China's Ministry of Housing and Urban-Rural Development (MOHURD) started to promote landscape architecture, architecture, and urban-rural planning with greater prominence within the field of human settlement and/or environment construction in China. Consequently, the focus and scope of investment being used to shape urbanisation in China lacked, until recently, a conceptualisation or working knowledge of landscape (Li et al., 2005). Although there has been retention of some classical Chinese garden design philosophy in contemporary development, this has had a minor impact on urban planning in China.

Notwithstanding these changes, the historical process of political, socio-cultural, and economic development in China and the UK have shaped the ways in which nature has been integrated into cities. In the UK, urban greening is associated with the use of nature in investment as a metaphor for wealth accumulation, which improves the living environment of the middle classes from the Victorian period onwards. This drew on an interaction of ideas and philosophies to frame nature as a socio-cultural and ecological entity. China's closed-door policy limited the exposure to diverse landscape practices and supported an internalised promotion of its own culture and philosophy in the making of the modern environment. After opening up in 1978, this has been addressed, to some extent, through the integration of Western knowledge, drawing heavily from importing concepts from North America, which has undermined the continuity of use of China's garden and landscape culture.

7.7 Urban Landscape Spatial Planning in China

It has been argued by McMichael (2005) that nature plays an important role in cities because the love of nature, wildlife, and ecology is a human need, which is linked to the relationship between people and their evolutionary interactions with the landscape. Fresh air, clean water, flora, wildlife, and other natural systems can be framed as basic human needs for those who dwell in cities. However, establishing links between these views and landscape ecology is a relatively new phenomenon in China. As a consequence, the study of ecology in urban public open space has been limited. Furthermore, as Tuan stated, the city came from the wilderness, and in the countryside, human beings can feel order, freedom, and glory as well as stress. "Order" is derived from the ecological order of wilderness, and "freedom" comes from the city. Unfortunately, the city's chaos also promotes additional mental and physical stresses, and in this case, the joy from the countryside becomes a necessary opposite to urban areas (Tuan, 1974). The ideal city should therefore not only symbolise freedom and order but should also include the pleasures of gardens, farms, and country life. Therefore, public open space in the city is considered necessary by many and important in providing a more idealised structure for human beings (Lynch, 1960). The rate of urbanisation seen in Europe and North America, and more recently in South and East Asia, has disturbed this balance and effectively reduced the proportion of natural and semi-natural ecosystems in urban areas (Public Health England, 2020). This resulted in public open space, including parks, gardens, squares, and allotments, being promoted as essential infrastructure for people who live in cities by urbanists and environmental specialists (Dehaene & Cauter, 2008).

Following the growth witnessed in the twentieth century, there has been a continuing rapidity to urbanisation in Chinese cities in the twenty-first century, with population density and sizes outstripping European cities (Sit & Xue, 2010). Also, as real estate speculation has increased with 'open market' reforms in China, there has been a corresponding decrease in the provision of private open space and public green and open spaces (Logan, 2011). Public space is very intensively used in China's cities. Therefore, as the urban population of China increases, greater demands are being placed on these spaces. However, attempts to promote green and public space provision have been limited as the concepts of urban ecology, conservation, and sustainability have historically been considered as 'Western imports' in China.

To help address this dislocation, the study of ecology commenced in the 1980s at a national academic level in China and gained credence in the 1990s, as political commitments to sustainable urban planning increased (Song & Gao, 2008). In 2007, the importance of ecology was for the first time positioned at the highest official level, when Chinese ex-President Hu Jintao stated in his report to the 17th National Congress of the Chinese Communist Party that China needed to build an economy based on eco-civilisation (Hu, 2007). This included a promotion of the development of an industrial structure, development modes, and consumption patterns that feature energy conservation and ecologically focussed environmental protection (Clark, 2009 p.48).

The structure of Chinese cities remains in transition. Due to the expansion of real estate speculation in the forms of housing and the accompanying transport and economic infrastructure, the provision of public space and landscape-scale spatial planning has been limited. There are, however, a range of urban parks, squares, and riverside walks being developed in China with a significant number being built since 1978; however their function and design may not serve communities as effectively as in other places due to their peripheral location or lack of amenities. Furthermore, the lack of planning expertise, a reliance on the importation of Western practices, and an ongoing failure to address urban landscape issues such as inaccessibility, perceptions of safety, parks that lack ecological diversity or socio-economic functions, and the privatisation of public space (Yang & Hu, 2016) can limit the value of urban landscapes. As a response to these perceived deficiencies, there has been an increased level of thinking focussed on the provision of green infrastructure within landscape and urban planning across several scales. This has been important in engendering a level of environmental understanding that goes beyond the site to a more network-centred perspective. Following the period of importation of Western ideas (remnants of which remain in practice), China is transitioning to new theories and practices focussed on the development and delivery of public open and green space planning.

7.8 Urban Landscape Space Planning in the UK

In contrast to China in the aftermath of the Second World War and the subsequent process of reconstruction, the concept of ecology was gradually integrated into planning in the UK (Fitter, 1946). Examples include the development of 'new towns' that included a greater variety of flora and fauna in different urban habitats. In 1950, Birmingham's land regeneration handbook was presented (Chinn, 2003) after which the study of 'urban ecology' in European cities increased. In London, the protection of wildlife sites in the urban area commenced in the 1970s, and in the 1980s, the first European Symposium on Urban Ecology was held in Berlin. In 1982, the Greater London Council (now the Greater London Authority) established an urban ecology team who worked with the London Ecology Committee to deliver programmes of nature conservation. The legacy of these organisations includes the inclusion of conservation practices in the statutory London Plan from 2004 onwards (Douglas et al., 2011).

From the birth of the term urban ecology in Chicago in 1925, research on urban ecology has evolved continuously in European cities with urban biodiversity playing a significant role in urban public open space design and planning (Richter & Weiland, 2011). Generally, biodiversity planning aims to maintain natural habitats and ecological networks within and across cities and avoid the fragmentation associated with urban expansion seen in China and North America. On the one hand, it brings benefits for the conservation of different species locally and provides opportunities to manage landscapes and ensure a continuity of approach to species management in urban areas. Moreover, biodiversity can help humans connect with nature and help children build an appreciation of nature (Muller et al., 2010).

However, within landscape planning, all countries approach the management of the landscape differently. As such national specificity can be identified in the actions taken to plan for environmental resources. In Germany, for instance, the process of green space planning acts as the strategic level approach to planning, whilst in North America zoning, catchment management and larger-scale conservation efforts have been promoted as effective forms of management (Mell et al., 2017). In the UK, the concept of greenbelt and the landscape-scale spatial plan for cities such as London, historically, or Bristol, Glasgow, or Manchester more recently have been prominent forms of green space planning (Natural England, 2010).

Taking London as one example, it can be compared to the development trajectories of the mega-cities of China due to the rate and scale of development. However, environmental planning in London has a history of innovation, which can be traced via John Claudius Loudon's *1829 London Plan: Breathing Places for the Metropolis*, the first city plan to explicitly take a landscape architecture approach. Furthermore, the notion of protecting London's green spaces has a lineage outlined in the London Green Belt Council records that show that a Green Belt idea was first proposed by Sir William Petty in the seventeenth century. Restraining the growth of London is a core objective of the Green Belt and was influential in Howard's articulation of his Garden City goals. The management of growth has been retained in the National Planning Policy Framework (Department of Communities and Local Government, 2018) and remains one of the few areas of planning not to be fundamentally altered since its inception (Batchelor, 1969). However, the current form of Green Belt designations often overlooks the objectives related to agriculture, orchards, woodlands, biodiversity, recreation, and scenic quality originally proposed. The origin of these ideas, and their integration with peripheral belts, can be traced back to Loudon's 1829 proposal, where he wrote that:

> A late attempt in parliament to enclose Hampstead Heath has called our attention to the rapid extension of buildings on every side of London, and to the duty, as we think, of government to devise some plan by which the metropolis may be enlarged to cover any space whatever with perfect safety to the inhabitants, in respect to the supply of provisions, water, and fresh air, and to the removal of the filth of every description, the maintenance of general cleanliness, and the despatch of business. Our plan is very simple; that of surrounding London, as it already exists, with a zone of open country, at the distance of saying one mile, or one mile and a half, from what may be considered the centre, say from St. Paul's. This zone of the country maybe half a mile broad, and may contain, as the figure shows, part of Hyde Park, the Regent's Park, Islington, Bethnal Green, the Commercial Docks, Camberwell, Lambeth, and Pimlico; and it may be succeeded by a zone of town one mile broad, containing Kensington, Bayswater, Paddington, Kentish Town, Clapton, Lime House, Deptford, Clapham, and Chelsea; and thus the metropolis may be extended in alternate mile zones of buildings, with half-mile zones of country or gardens, till one of the zones touched the sea.

Following Loudon, Sir Patrick Abercrombie's County of London Plan 1943–194 included a chapter focussing on Open Space and Park systems. It modified the dominant ideas of the 1929 plan and linked them to a visionary planning concept: the creation of a coordinated Park System for the Region of Greater London. Joseph Paxton, who is best understood as the inheritor of 'Loudon's mantle' and therefore held an influence on practice in London, would design Birkenhead Park (1847) in Wirral as the first publicly funded civic park in the world taking Loudon's ideas forward. Moreover, Paxton's plan for Birkenhead Park is widely considered to be the inspiration for Olmsted to design The Central Park (1876) in New York.

The provision of large-scale parks though has been limited in the twenty-first century. Although the Victorian era established a pattern of landscape development linked to wealth creation and philanthropy, this has not continued. Furthermore, as land values have increased, the rationale for investment in green space has been difficult to support. Consequently, the spatial footprint of green space across the UK varies. However, due to the historical legacy of permissive access, there remains a network of linear spaces that, in some cases, act as core links between urban areas and the wider landscape. Subsequently, the location of green walkways, footpaths, and Public Rights of Way (PRoW) are the spatial connective features between parks and open spaces. In Britain's second largest city, Birmingham, the Harborne Walkway created a 2.5-km route utilising a disused railway line from Summerfield Park to Harborne to promote walking, cycling, and engagement with the landscape (Dargue, 2010). Waterways have also been a key resource used to connect people with open space. Comparable examples exist in rural areas with the Honeybourne Line walkway/cycle in Cheltenham acting as a popular connective route, as well as an important wildlife corridor, and was built on the abandoned Honeybourne Railway Line (Cheltenham Borough Council, n.d.).

To summarise, new urban landscapes in China are designed with a background of rapid urbanisation. Although an extensive evidence base exists promoting the inclusion of nature in the city, it is not considered within the strategic planning stages of urban planning in all cities. Where green space has been considered, it relates more directly to existing spaces, i.e. gardens or the use of Western ideas to frame design. In contrast, the British use of open space and greenway and Green Belt planning has developed over an extended timeframe shaping the development of urban parks, linear features, and the rise of green infrastructure planning. There has also been a direct interaction and exchange of practice between the UK and North America that has influenced elements of contemporary landscape architecture.

7.9 Green Infrastructure and City Planning in the Twenty-First Century

In July 2019, London was officially declared the world's first National Park City. National Park Cities are inspired by the UK family of National Parks, but it differs as it is a 'large urban area that is managed and semi-protected through both formal and informal means to enhance the natural capital of its living landscape' (London National Park City, n.d.). In 2017, Tianjin Urban Planning Borough published for the first time the central urban open-space system design plan, which included a green grid system, and proposals to monitor the city's environmental grid, especially its waterway plan. The Tianjin plan differs from the spatial composition of the London discussions as it does not include the greenbelt or spatial plan set out by Abercrombie historically or in the current London Plan consultation. Alternatively, Tianjin's plan focusses on the development of a new city park, but not a system of parks. Furthermore, the accessibility of the green/blue system requires further clarification and investigation to assess its utility in Tianjin (Tianjin Urban Planning Borough, 2017).

It has also been argued that inaccessible green infrastructure does not allow users to find the space, so these spaces may lack functionality or patronage. Gillham stated in the *The Limitless City: A Primer on the Urban Sprawl Debate* (2002) that accessibility should be the main consideration in the design of public open space, and significantly, it should relate to public playgrounds, playing fields, and neighbourhoods and promote use by pedestrians. During the late nineteenth century, when problems with the limitations of the configuration of public space in cities were being debated, the main criticism was an imbalance in the distribution of parks and commons. At the time, suggestions focussed on having smaller, more accessible inner-city spaces, and in London, opening up its garden squares to the public. The inclusion of such practices differs in China where the first Speciality Committee on Urban Ecology (CUE) was first held in 1984 at the Second Conference of the Ecological Study of Urban Areas (Chen, 1989). The concept of urban ecology was imported to China and influenced the economy, ecology, and geography, as well as urban planning. It has also been argued that 'population speculation-land use-infrastructure layout' has been proven to be invalid in dealing with the swiftness of urban development issues and is largely responsible for the degradation of ecological conditions and the chaotic situation of the current Chinese cities (Richter & Weiland, 2011).

At the beginning of 2018, the concept of the 'City Park' was for the first time announced by Chinese President Xi Jinping when he inspected Tianfu New Area. President Xi urged the local government to plan Tianfu New Area well, to place their emphasis on highlighting the characteristics of parks in cities and taking ecological value into account. Xi's proposals were considered to clarify that Park City is not an equivalent to Park + City but an integrated process that includes various models: greenways, Shan-Shui, and town and/or country approaches (Xiao et al., 2018). It also promotes a people-park-city system highlighting that the value of ecology is important to the lived experience of residents and can be considered to support increased GDP via improved urban liveability. China's Park City idea is the first articulation from the China's government prioritising urban ecology in its development agenda and could be framed as a Chinese version of bringing nature into the city like the Victoria Era in Britain. Based on Xi's explanation, the Park City will promote green networking and improve the spatial quality of green infrastructure in urban areas. It is unknown whether the Park City concept in China will continue to learn from Western models or follow the classical Chinese Garden philosophy.

In the UK, the development of more innovative green space planning is invariably being linked to health, well-being, climate change adaptation, and economic growth rather than landscape quality per se. Although landscape architects have integrated aspects of historical landscape aesthetics, i.e. the now debunked Garden Bridge in London, there has been a far greater emphasis placed on landscape diversity and providing opportunities for multi-functionality and interactivity. The landscape diversity of the London Olympic Park illustrates a more effective integration of people, place, and nature that can be missed in many development projects, for example. The inclusion of an increased quality and quantity of green infrastructure within development has been linked to effective advocacy by environmental organisations and illustrates a growing knowledge exchange between planners, landscape professionals, and developers. Critics remain though regarding the overreliance on green belts or formal parks as the main form of landscape investment. However, the retrofitting of green walls, green roofs, parklets, and reuse of waterways across Birmingham, Liverpool, and Manchester has shown willingness to engage with alternative approaches to landscape architecture.

7.10 Conclusion

The rise of a green infrastructure perspective to landscape and urban planning has been facilitated by a transdisciplinary and trans-locational exchange of knowledge. Whilst many cities continue to utilise the historical legacies of their dominant landscape architectural styles, there has been a transition to a more diverse approach to design and implementation over the past 20 years. In many cases, this has limited the ongoing integration of the social value of classic styles of landscape design, which have been replaced with the homogeny of internationalised consultant practices, i.e. a Westernisation of practice in China. However, we can identify a residual use of classic styles, approaches, and concepts in both China and the UK, that have been integrated into an understanding of urban planning. Furthermore, green infrastructure planning has started to be located within discussions of planning at several scales. In the UK, this is achieved through multi-scalar thinking, whilst in China, the dominant approach remains the project scale. We can though argue that there is a growing comprehension within planning and landscape architecture that draws on the artistic, the historical, and the contemporary to orchestrate a symphony that integrates landscape, nature, and urban form. The conductor may therefore be the landscape architect, with green infrastructure acting as the melody to create the harmonious connection between people and nature.

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Chapter 8
Greenways as Structures for Urban Change. Milan and Beijing Facing Post-industrial Regeneration

Luca Maria Francesco Fabris and Mengyixin Li

Abstract The metropolis of Milan (Italy) and Beijing (China) – even with their differences in the number of inhabitants and dimensions – can be taken as references for Europe and Asia as both are included in the list of Innovations Index (2018) with a comparable rank position (Beijing #37; Milan #40). In the last decades, both administrations have started redesigning their urban territory considering the profound transformation in their administrative, educational and cultural centres. This chapter reports the evolution of the post-industrialisation effects on sites in Milan and Beijing and their regeneration as parts of new green networks that represent an ultimate infrastructure based on a series of landscape components. Over the past 50 years, in both metropolises, a kind of parallel progress has endeavoured to apply concepts, strategies and models developed in landscape and environmental design theory. Milan is now a town demonstrating that change derives from opportunities linked to the presence of a strong network of public open spaces, while Beijing is transforming its consolidated built urban fabric by applying the Shan-Shui City and Sponge City processes.

Keywords Green Infrastructure · Climate Adaptations · Healthy City · Beijing · Milan

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8.1 Introduction

Ecology, sustainability, resilience and the new general environmental awareness are increasingly influential in the design of public-use landscapes. Since the 1980s, landscape architects have been designing industrial wastelands, former mining regions and urban voids between housing developments and highways. Gilles Clément gave us the definition of the ‘Third Landscape’, which has the potential to preserve biodiversity. Facing the post-industrial towns’ transformation, the idea of developing derelict spaces into valuable environmental-friendly living spaces permits a balance between ecological issues and urban development. The André Citroën Park in Paris, realized from 1988 to 1992 by Gilles Clément and Alain Provost on the site of a former car factory, is a playful design which is diverse from any other Parisian greens with its obliquely arranged, rectangular lawns, a white and a black garden and a square where children can run through water fountains. Architectural elements, water features and plants form poetry of severity and wit. In 1988, also in Paris, landscape architect Jacques Vergely and architect Philippe Mathieux presented the Promenade Plantée, one of the first urban greenways realized by transforming a former railway. The fortunate High-Line in New York (2009–2015)[1] pays tribute to this primary reference. Just a few years later, in Germany, the Duisburg Nord Landscape Park, designed by Peter Latz, and the Lausitz Region in Brandenburg, full of abandoned coal mines, have been revitalised through reforestation and landscape design, creating new green corridors networks currently present in the areas formerly developed by IBA Emscher Park (1988–1999) and IBA Fürst Pückler Land (2000–2010). If we move our focus from Europe to the USA, Richard Haag’s Gas Works Park in Seattle is an unusual public park located on the site of a former coal gasification plant on the shores of Lake Union opposite downtown Seattle. In 1975, the 19-acre site, acquired by the city in 1962 after the shutdown, opened to the public as a park. Every survey of twentieth-century landscape architecture studied the Gas Works Park as a modern work that challenged modernism by engaging a toxic site and celebrating an industrial past. Haag’s work with ecologists and soil scientists in these landscape remediation and reclamation projects opened new scenarios of inquiry into the adaptive reuse of post-industrial sites. To describe his design philosophy, Haag encapsulates the correct approach to design in just six words: ‘Space-Scale-Circulation-Earth-Water-Plants’, combining the generative power of Nature with the volitional nature of all human activity (Fabris, 2010).

The authors recently proposed (2020) a reading of the history of post-industrial landscape transformation that has occurred in the last 50 years identifying four historical phases: soft, firm, structural and merging post-industrial landscape transformations. The whole process fully reveals landscape transformation evolving from embryo to maturity. The landscape approach has become a scientific means to solve complex social and environmental problems, and we can consider abandoned

[1] A project by architects Diller, Scofidio and Renfro in collaboration with landscape architects James Corner (Field Operations) and Piet Oudolf.

industrial areas as experimental laboratories. The First Phase (Soft Transformation, from the early 1960s to the late 1970s) represents the beginning of the post-industrial landscape transformation. Due to the transformation of industrial structure and the implementation of new production technologies, with the rise of ecological thought, especially under the influence of Rachel Carson's *Silent Spring* (1962), early ecologists carried out extensive discussions of an ecological and environmental crisis that seriously threatens the whole biosphere survival compromised by human behaviour. This stage embodies the initial characteristics of post-industrial landscape transformation: The post-industrial area renewal was an inevitable result of industrial change; under the influence of ecological crisis, the problem of abandoned land renewal gradually aroused professionals' attention. Landscape architects had a tentative understanding of the post-industrial landscape, and facing complex practical problems, they tried to explore the renewal of the post-industrial area through interdisciplinary means. In the Second Phase (Strong Transformation, from the early 1980s to the late 1990s), the post-industrial areas had been developing rapidly and the related theoretical research and practical explorations had spread.

The coexistence of the end-of-work tragedy, the closure of many heavy industrial plants and the birth of the ecological movement stimulated a drastic change in the post-industrial landscapes. Intervention measures at the social, ecological and legislative levels emerged. The renewal of industrial wastelands achieved a coordinated transformation between human intervention and ecological processes. The substantial transformation presents blending of the 'decadence' of artificial work (the industry) and the 'wild' of nature (Herrington, 2008). The Third Phase (Structural Transformation, after the start of the second millennium) faced industrial plants made obsolete by scientific research and technological innovation, which often led to the construction of new plants even before the dismantling or renovation of the existing ones. However, on the wave of the increasing importance of the principles of ecology and sustainability, and with the launch of ecological awareness policies, a whole series of principles were implemented, allowing planners to reshape the industry and redesign the territory through multi-scalar interventions. This period shows the particularity of the post-industrial landscape transformation: New green space policies promoted the scale and speed of post-industrial areas' renewal, and 'landscape' became a structural tool for the development and renewal of post-industrial areas. In the Fourth Phase (Merging Transformation, the recent years), the innovative concepts of urban resilience and metabolism have been evolving under the notion of sustainability (1987): integrated into landscape design, the post-industrial landscape transformation interesting the global context has shown merging characteristics. Our metropolis is interpreted as an open and complex organism always struggling to reach a perfect equilibrium that brings advantages to human inhabitants and all the components that create a city. The social, economic, environmental and other factors and their interrelationships are coupled with the urban system through material circulation and energy flow to form a continuous spatio-temporal dynamic process. Based on this perspective, the urban landscape represents both the natural, spontaneous succession system and urban autonomous development process and has the characteristics of mobility, heterogeneity, self-organization and metaphor. At the territorial and urban level, perspectives, dimensions and contents of the post-industrial area renewal are more comprehensive and open, presenting a diversified development trend toward the future.

According to the matrix presented in this preface, all the study cases reported in this chapter have in common the goal of forming or being part of (urban) green corridors networks, most of them combining slow connections (walking and bicycle lanes) with plants (from simple floor-beds to high reforestation trees) permitting new fluxes of biodiversity through the consolidated urban fabric.

8.2 Milan

The green transformation in Milan comes from its historical background and some visions developed by researchers and designers in the last 30 years.[2] At the beginning of the Third Millennium, the capital of Lombardy transformed into a mere services centre. This change modified its territory, brownfields replaced industries and logistic compounds, and derelict areas dotted the urban fabric. Now Milan has an environmentally friendly policy as its first aim, and its post-post-modern condition (no more industries within the city borders, and all the economy moved by trading, services and culture) brings the Italian metropolis to be one of the greenest cities in Europe. Milan can count in its attractions one of the most ancient public parks in Europe, the 'Giardini Pubblici' (Public Gardens), opened in 1784 by the Austrian Government to bring into Lombardy Vienna's grandeur. However, after two centuries, the town started to face the issue of green structure loss, overwhelmed by the continuous growth of the urban fabric. Two vast parks devoted to the idea of reforestation created a new definition of Milanese outskirts were the solution to stop this trend: Boscoincittà ('Wood-in-the-town'), which represents the requalification of former agricultural fields, and Parco Nord Milano (Northern Milan Park), recovering the brownfields left by the steel industry. Both are dedicated to recreational use and have bettered the life quality of the individuals living in Milan. Ending the twentieth century, a new series of district-scale parks substituted some former abandoned industrial areas left in various places inside the Milanese historical urban context. Finally, in the last 10 years, Milan has essentially started a new urban planning regeneration programme that changed its skyline. This 'revolution' came together with many new parks and open spaces directly connected with the built environment reserved for residential or office use. This timeline and the following reports reveal how green open spaces and a continuous urban greenways network changed Milan. The metropolis has evolved into a green-growing and resilient city able to adapt to climate change challenges.

[2] The authors have illustrated these historical passages also in other writing, as in Fabris et al. (2019).

8.2.1 The Milanese Green Outskirt Connection

Despite its great stretch, Parco Nord Milano[3] is an urban park connecting greenery from distinct heritages. Derelict industrial areas, a former airport site and country fields converge to create a complex park network linked by a broad series of pedestrian and bicycle paths. Meadows and woods are located together with horticultural gardens, light sports activities services and wildlife sanctuaries over a surface of 680 ha, surrounded by one of the densest urban fabrics in Europe. Parco Regionale Agricolo Sud Milano[4] (Southern Milan Regional Agricultural Park), founded by Region Lombardy to preserve a fascia of agrarian land from the urban sprawl, is a green buffer zone between Milan and the other outskirts municipalities. This park is the widest in Milan and less structured as its reason is to hold a green belt devoted to cultivation (as the ancient rice fields) otherwise condemned to disappear around the inner metropolis. The interaction with the visitors happens through wandering paths, allowing visitors to experience country life in less than 30 min of walking from the town centre. The name of Boscoincittà[5] is programmatic. The concept was to offer a few minutes from Milan centre the possibility to experience natural wood from the reforestation of former agricultural areas abandoned for years. This straightforward strategy had a sudden success that brought the expansion of the initial Boscoincittà into a system with other two parks coming from the reclamation of the former derelict areas: Parco delle Cave[6] (Park of Pits) and Parco dei Sentieri Interrotti (Park of the Broken Paths). This system offers specific recreation activities, from the most 'urban' as the vicinity park to the wild emptiness of the prairie, just in a walk of a few kilometres. Even if these parks have succeeded in giving Milan citizens the recreational activities they requested, the City of Milan Administration does not currently support them.

Even if the times for a change were mature, Milanese Administration took time to understand that in the late '90s of the last century, the town was, all in all, a post-modern city. The PhD thesis *Post-industrial Green* (1996, published in 1999), developed by the author Luca MF Fabris, has been one of the first tries in Italy to bring together environmental design and landscape architecture, illustrating the opportunities connected to the reuse of derelict industrial areas. Starting from the analysis of several international case studies, Fabris proposed for Milan the creation of a green corridor connecting all the brownfields existing in its territory, creating a network of cycle-pedestrian paths heading to the historic centre. One of the most relevant results of this study has been to prove that soft greenway structures built with naturalistic engineering techniques and the residents' participation were possible without high costs (Fig. 8.1).

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[3] Parco Nord Milano covers an area of 680 ha; website: www.parconord.milano.it

[4] Parco Agricolo Sud Milano covers an area of 46,300 ha, website: www.parcoagricolosudmilano.it

[5] Boscoincittà (together with 'Parco dei Sentieri Interrotti) covers an area of 110 ha; website: www.cfu.it

[6] Parco delle Cave covers an area of 135 ha; website: www.cfu.it

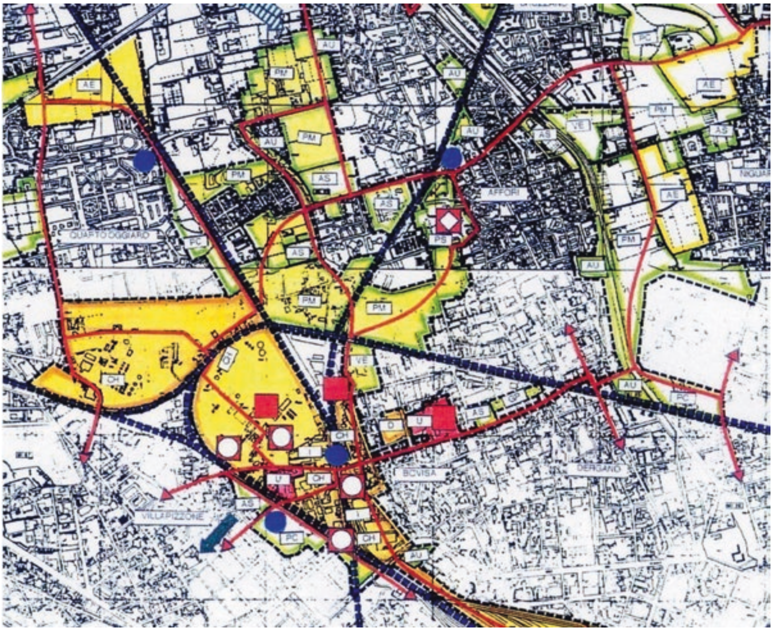

Fig. 8.1 Detail of the Greenway in the Milan-Bovisa post-industrial area, (LMF Fabris' PhD Thesis project 1996)

Ten years later, the Province of Milan asked Stefano Boeri, director of Multiplicity Lab at Politecnico di Milano, to design a plan for an 'ecological network that aims to achieve physical, social and cultural connections capable of making our province more liveable'.[7] The 'Metrobosco' (Metropolis' Forest) (Fig. 8.2) proposal presented by Boeri connects all the existing natural areas, including the Parco Sud, which 'represent the ideal integration between environmental protection and productive development'[8] for the completion of new green and sustainable metropolitan area.

Another project for a new pedestrian and cycle paths network enriching the Milanese urban fabric with greenery to enhance the city and inhabitants' daily life through slow mobility was the 'Raggi Verdi' one (Green Rays, 2007) (Fig. 8.3).

The Green Rays were planned to contain linear open spaces shadowed by thousands of trees 'where one can walk, laze, run, ride a bike enjoying the green already present on the Milanese urban territory: a garden, a tree-lined square, a neighbourhood park, a large park urban'.[9] The scheme arose from the Milanese Metropolitan

[7] Provincia di Milano's press release for the launch of Metrobosco project (July 13, 2006). Unfortunately, the project vanished, but after years became the starting point of the 'ForestaMi' project, presented later in the chapter.

[8] Ibidem.

[9] Press release, City of Milan and AIM (May 27, 2007). Most of the project has been unattended.

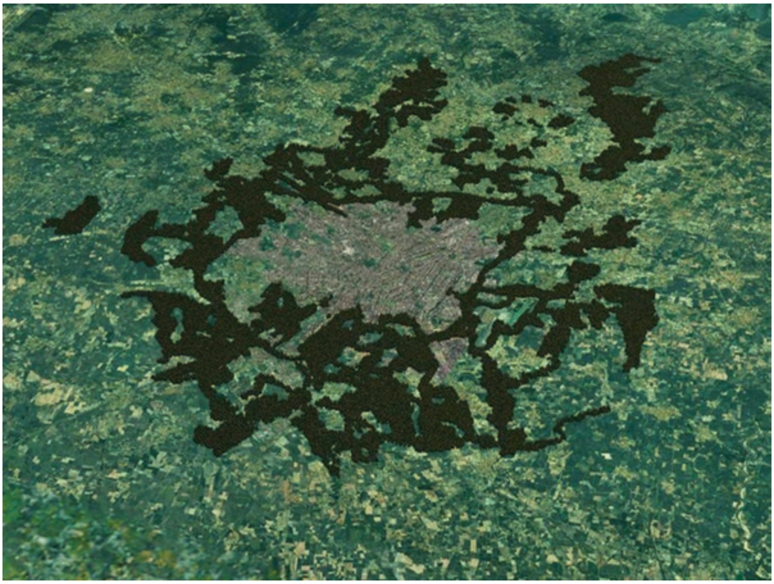

Fig. 8.2 "Metrobosco," a project by Multiplicity (director: Stefano Boeri), Politecnico di Milano. (Courtesy SBA, 2006)

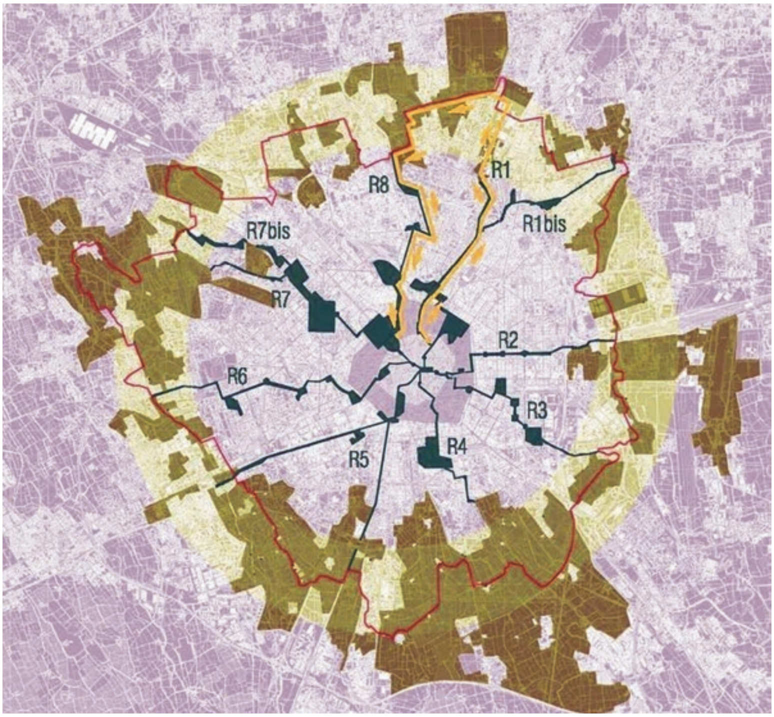

Fig. 8.3 The Milan "Raggi Verdi" (Green Rays) Plan by LAND (2007), courtesy LAND

Interests Association (AIM) with Studio Land (Andreas Kipar) and found a place among the agendas concerning the candidacy for the 2015 International Expo. The project included eight Green Rays of an average length between 7 and 12 km. On the map, each radius, starting from the city centre, arrives at one of the large urban or peripheral parks already part of the Milanese belt. All these projects were utterly unfinished, but their proposed ideas were seeds that have remained alive for more than a decade, waiting for the development of other proposals to create a greenway network in Milan.

Meanwhile, some central former industrial areas in Milan were finally ready to be incorporated into the consolidated urban fabric. It was clear that the wild greenery had transformed these areas from the inside after years of abandonment. Nature operated over these derelict areas with a power and a smartness that humans cannot have, revealing what Germans researchers called 'Industrienatur'.[10] Hence the decision to intervene by keeping the past 'memory' in the reconversion projects. The Rubattino Park[11] and the OM Park[12] are the best examples of this new way to realize green areas in Milan that, due to their dimensions, respond to the needs of residents' families and the elderly.

8.2.2 The New Urban Greenways in Milan

At the advent of the new millennium, Milan faced the transition from a post-industrial to a post-post-industrial town and the economic recession that crossed the world. This picture in motion also includes other elements. The city of Milan managed, after 50 years, to adopt a new General Master Plan that proposes green and open spaces as essential attributes of its urban fabric. In 2015, Milan became EXPO City, embracing sustainability, agriculture and food culture as its credo. These new ingredients have changed 'on the rush' the urban structure of a city that wants to change its lifestyle, combining the needs of economic development with those that can guarantee the achievement of objectives such as well-being and happiness. This new Milanese life vision stream brought to the planning of new public green spaces, such as the CityLife Park[13] (when completed, it will be the primary public park in

[10] This noun was conceived by the team of IBA Emscher Park 1988–1999 (Director Karl Genser) to describe the transformation operated by Nature on the derelict industrial areas.

[11] Parco Rubattino (former Maserati Industries area) covers 27.4 ha, but it is still not entirely built. Project by Andreas Kipar, Land Milano.

[12] The 'Parco delle Memorie Industriali' (Industrial Memory Park), known better as OM Park (in the area were the OM Lorry Industries), covers 31.4 ha. Project by Andreas Kipar, Land Milano.

[13] The CityLife Park (2016-ongoing) will cover an area of 17 ha when completed. Project by Gustafson Porter.

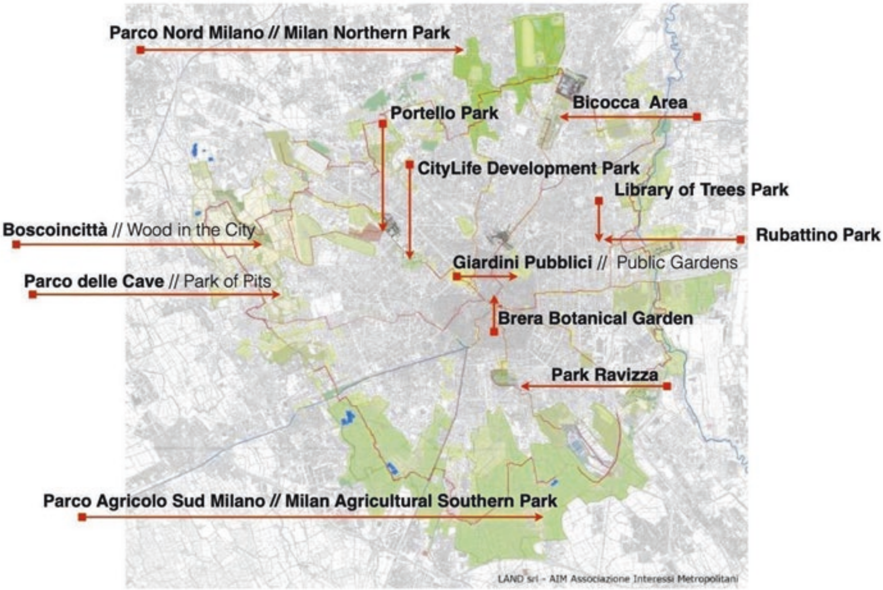

Fig. 8.4 The Milanese green belt and parks. (Elaboration by the Authors. Map courtesy LAND and AIM)

inner Milan), the Portello Park[14] and the 'Library of Trees' Park.[15] All these parks come from a requalification process and integrate different district zones in the lost valuable parts of Milan, and they will be part of the forthcoming greenways network of Lombard town (Fig. 8.4).

Nevertheless, what happens on the outskirts of the town? Even there, the way to approach derelict areas has changed. The city of Milan, raising its fortune in the international tourism panorama, has evolved from a shrinking town, losing population decade after decade since the 1970s, passing from 1.7 million (1971) to 1.2 million inhabitants (2011), to a new people's attractor starting again in increasing its population, reaching currently 1.4 million inhabitants.

Unlocking a new chapter in its history, the city of Milan chose to bet on the potential present in ignored places, converting them into parks, as happened with the 'Giardino Franca Rame' (Franca Rame Garden)[16] – a simple and well-designed green structure that offers recreational and social spaces for a part of the town lacking open and green areas. In the last seven years, the new administration's policy

[14] The Portello Park (completion 2018) covers an area of 7 ha. Project by Andreas Kipar, Land Milano and Charles Jencks.

[15] The "Library of Trees" Park (opened in Fall 2018) covers an area of 9 ha. Project by Inside-Outside (Petra Blaisse).

[16] The Franca Rame Garden (opened in Spring 2016) covers an area of 6.2 ha. Project by Studio Franco Giorgetta.

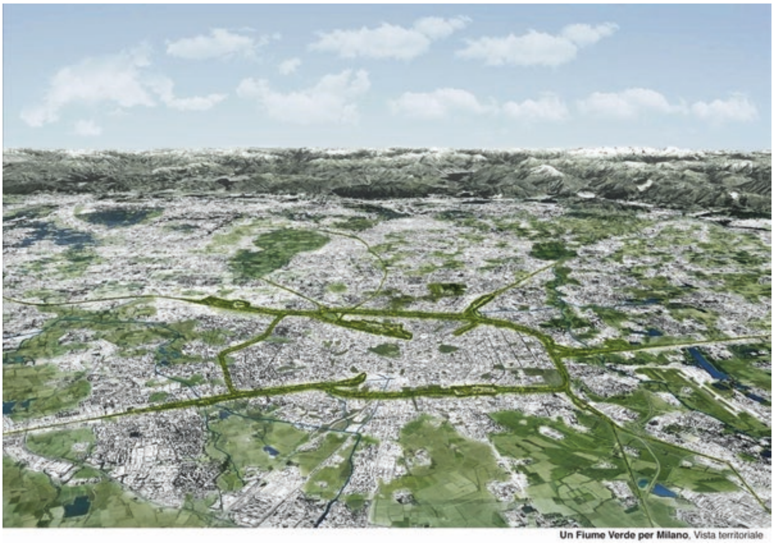

Fig. 8.5 Fiume Verde (Green River) for Milan, a project by Stefano Boeri Architetti. (Courtesy SBA, 2017)

encouraged the requalification of abandoned areas (actions 'Re-shaping Milan' 2015 and 'Re-shaping Milan' 2018, developed with the Politecnico di Milano) and asked the Italian Railways' Sistemi Territoriali[17] to give back to the town seven unused railyards within the city territory.

This demand, also endorsed by the ordinary people – asking more and more for green spaces and slow mobility in the town – was actualized with the visionary plan 'Fiume Verde' (Green River, 2016) (Fig. 8.5) by Stefano Boeri Architetti. This proposal designed a net of inner greenways able to boost the metropolis' greenery surface intensely: 'The Green River is a project of urban reforestation that aims to achieve on 90% of these seven former railyards a continuous system of parks, woods, oases, orchards and gardens for public use – linked by the green corridors and cycle paths built on the railroad tracks' says Stefano Boeri, explaining that 'The Green River will cross the urban body of Milan … a unique opportunity to rethink Milan, combining urban development with the presence of continuous and accessible green systems, which improve air quality and ensure the protection and multiplication of urban biodiversity'.[18] In one year, the Green River could absorb 50 thousand tons of CO_2 and produce 2 thousand tons of oxygen with a total area of 1 million 100 thousand square metres of parks, hills, clearings and meadows.

A new series of projects arrived in the last three years, demonstrating how the sown seeds are sprouting and a greener and greener Milan is ready to emerge,

[17] Sistemi Territoriali (Territorial Systems) is the incorporation part of the Italian Railways Group that owns the Italian railways' stations' compounds.

[18] Press Release, Stefano Boeri Architetti Associati, April 2017.

Fig. 8.6 Former Farini Railyard Regeneration, a project by OMA + Laboratorio Permanente. (2019, Courtesy Laboratorio Permanente)

exemplifying how landscape and environmental design could be valid methods to regenerate a town, creating a new kind of territorial matrix where greenways combine with the existing urban fabric as a whole. In early 2019, OMA and Laboratorio Permamente[19] won the international competition of two Milanese former railyard sites. The competition brief combined two areas, one in the centre of Milan (Farini Railyard) (Fig. 8.6) and the other at the extreme western outskirts of the town (San Cristoforo Railyard). While in Farini, there is the possibility of building up to 40% of the area (the remaining part will be public green), the San Cristoforo area will host the longest linear park in the Metropolis. The two new parks will be active parts of the green corridors system. The whole project presented unique ideas, and some of them became more interesting with the pandemic emergency. The Farini plan is structured to be resilient to diverse scenarios, from an ongoing economic crisis (worst) to a vibrant, fast-growing economic scenario (best). The only thing that persists in any future alternative is the green structural system, a kind of green spine that is the base of the regeneration program's first phase. This intervention will be at a low cost and flexible according to any development of the Farini Area. At the same time, the San Cristoforo Area (Fig. 8.7) will become a kind of representation of a Sponge City,[20] with an artificial lake that depurates the rainwater and creates its

[19] OMA and Laboratorio Permanente led a group of international professionals as the landscape firm Vogt Landscape Architects and Philippe Rahm architects, among others and won the international competition with the entry' Climatic Agents'. The Farini Area has a surface of 42 ha, and the proposal indicates more than 31 ha for public green areas. The San Cristoforo Area is 14 ha of surface.

[20] Please refer to the section about Beijing in this chapter to read the definition of Sponge City.

Fig. 8.7 Former San Cristoforo Railyard Regeneration, a project by OMA + Laboratorio Permanente. (Courtesy Laboratorio Permanente, 2019)

microclimate, contributing to wellness in Lombardy's capital. Both these projects present a high grade of experimentation, and Milan could demonstrate new ways to implement green surfaces within the built environment.

Two years ago, Studio Barreca & La Varra (Fig. 8.8) presented the project 'Innesto' (Grafting) for the former Greco-Breda Railyard area. This scheme[21] has a strong urban connotation, devoted to realising a new green node reconnecting after more than a century two parts of Northern Milan divided by the railway corridor heading to Switzerland.

This built and solid urban core will develop over the line traced by the green corridor coming to the centre from the North Park. The shape of the settlement adapts to the green primary structure, introducing landscape as a novel parameter valid for organizing the future asset of a well-performing city.

In 2021, Carlo Ratti Associati won the competition for the Former Porta Romana Railyard's master plan as part of the Olympics project Olympic Winter Games 2026 Milano-Cortina. This regeneration project will be the green junction between two new important cultural and business areas in Milan (the New Bocconi Campus, designed by SANAA on the Northern side, and Prada Foundation, designed by OMA, and Symbiosis Business District, designed by Studio Antonio Citterio Patricia Viel and others, on the Southern side). In this case, Ratti, starting from the concept expressed by the Boeri's Green River scenario, keeps in his winning

[21] The 'Innesto' project by Barreca & La Varra has been one of the winning entries in the international competition 'C40 Reinventing Cities'. The nZEB neighbourhood covers 6 ha and presents a rate of 72% of green surfaces that will host 700 new trees and several other green features.

Fig. 8.8 Former Greco-Breda Railyard Regeneration "Innesto" (Grafting), a project by Studio Barreca and La Varra. (Render courtesy Barreca and La Varra and Wolf Visualizing Architecture, 2020)

proposal the majority of the former railyard as a green public surface, being part of a continuous greenway network that, thanks to other spotted interventions, permits the greenery to arrive inside the consolidated urban fabric.

Since the Covid-19 pandemic, Milan has been ready to react to the various lock-downs, thanks to the inhabitants' unexpected reappropriation of the green open spaces and the Public Administration implementation of several projects based on the 15-Minute-City and the Tactic Urbanism methods approaches. All these new projects, redefining a more human scale into the open public spaces by design and use, have been easily and quickly arranged as the greenways' structure was present and vital even if forgotten. The urgency to reuse the town in a new, more liveable way during the days of lockdown (one of the few things possible to be done was the 'personal and distanced walk' in the neighbourhood) has pushed the administration to act promptly by rediscovering studies and proposals that have remained in the drawers for decades, as described in Fabris et al. (2020). In this list of new projects, we must also include the redesign of the Former Expo 2015 Areal, now renominated 'Milan Innovation District – MIND' by Carlo Ratti Associati with LAND (Andrea

Fig. 8.9 Former Expo 2015 Areal Regeneration MIND Park, a project by Carlo Ratti Associati with LAND. (Courtesy CRA, 2019)

Kipar). This project converts the 1.5 km long concrete platform axis of the exposition compound into a section of a new green corridor connecting the North-West outskirts of Milan to the city centre, passing through the Former Farini Railyard Area presented before. The new sustainable buildings in the new MIND (Fig. 8.9) will take advantage of the green network in perfect osmosis with the public open spaces. Last for the moment is the 'SeiMilano' Development by Mario Cucinella Architects, one of the largest private real-estate settlements designed in Milan and currently under construction in the western outskirts of the town. SeiMilano will introduce a new 16 ha public park planned by the French landscape architect Michel Desvigne (Fig. 8.10). This project presents an inversion of the proportions between built and green areas as we were used to seeing in Milan only some years ago.

As the last point of this story of change, it is to underline the importance of the 'ForestaMi' ('Forest Milan', but also readable as 'Forest-Me', 2019 – ongoing) project[22] promoted by the Metropolitan City of Milan, the Municipality of Milan, the Regional Council of Lombardy, Parco Nord Milano, Parco Agricolo Sud Milano, ERSAF (Regional Agency for Agricultural and Forestry) and Fondazione di Comunità Milano. ForestaMi involves planting 3 million trees by 2030 to clean the air, improve living conditions in Milan and counter the effects of climate change. Collaboration between all the promoters has made it possible to achieve a strategic

[22] This project is the outcome of the research carried out by the Department DASTU of the Politecnico di Milano (Director prof. Maria Chiara Pastore) with the the support of Falck Renewables and FS Sistemi Urbani.

Fig. 8.10 "SeiMilano" Park and Real Estate Project, a project by Mario Cucinella Architects (architecture) and Michel Desvigne (landscape architecture). (Courtesy MCA and Michel Devignes, 2020)

view of the role of greenery in the metropolitan area of Milan and to start a process of registering, enhancing and implementing all green infrastructures with trees in order to promote urban forestry projects and policies as well as the construction of a Metropolitan Park in Milan (Fig. 8.10).

All these points introduce a new approach to city-making, based on acknowledging that the human future in towns can find its new and correct dimension only by recognizing the landscape and its open green spaces as the ultimate infrastructure.

8.3 Beijing

In terms of green infrastructure theories, the construction of greenways in European and American cities has gone through more than one hundred years of exploration. In the late nineteenth century, the greenways built by integrating parkways and greenbelts provided leisure functions. Since their conceptual development, the greenways have increasingly required the realization of multi-objective and multi-functional values. Greenway function has constantly evolved as a result of a deepening understanding of needs and demands. From an initial street-like space focusing on landscape functions to a comprehensive green space system with ecological network functions, the linear greenways emphasize green space connectivity between urban and rural areas. They can express ecological, recreational, social and landscape values. Given the above-changing concept of greenways, Beijing, with a history of 3,000 years of city construction, has its cultural expression of urban greenway planning and construction, especially in the unique green conceptions of Shan-Shui City[23] and Sponge City[24] at the end of twentieth century.

As a matter of fact, with population growth and large-scale urban construction, Beijing has faced urban fracture problems of natural systems and public spaces. Researchers and planners fronted these challenges and opportunities to maintain the existing natural environment and garden or park greenways using the river courses and abandoned railways, opening lands to reform urban ring roads and constructing important green corridors in order to shape a complete green ecological network and remoulding integrated natural and public space systems in the whole territory. Against this background, green transformation at multiple scales has happened in the urban development pattern where industrialization and de-industrialization coexist. At the beginning of the twenty-first century, a growing number of researchers and designers in Beijing tried to find practical solutions to improve the green infrastructure system by employing landscape renewal, especially on derelict lands, within the top-down strategy of Land Vacated and Reclaimed for Greening, such as Beijing Zhangjiakou Railway Green Corridor in the network of Three Hills and Five Gardens Greenway[25] and Shougang Industrial Park[26] in the regional system of Yongding River Greenway.[27]

8.3.1 Green Conceptions of Shan-Shui City and Sponge City

Since the 1990s, Beijing's greenways development embodies the concepts of Shan-Shui City from the bottom-up planning perspective and Sponge City from the top-down policy. They have become essential ideas for the progress of green, resilient landscapes. The political idea of Sponge City in the view of landscape ecology means urban landscape as green or natural infrastructure, a widely recognized planning tool for nature conservation and regional and urban development referred to the 1990s understanding in Western developed countries. The concept borrowed the function of a natural sponge to create a metaphor which generally highlights the

[23] Shan-Shui City or Mountain-water City is an ideal city concept proposed based on the traditional Chinese view of the landscape and the philosophy of harmony between man and nature.

[24] In 2012, with freshwater shortage and urban flooding occurring in most Chinese cities, landscape architect Kongjian Yu proposed the concept of a sponge city or ecological city, which could act as a green sponge to improve urban functions of natural storage, permeation and purification, and a principle of ecological priority is accordingly established.

[25] Three Hills and Five Gardens is a collective term for the historical and cultural heritage represented by the Qing Dynasty imperial gardens in the northwest suburbs of Beijing, which are conserved and will be reused to develop urban greenways in the future.

[26] Shougang Industrial Park in Shijingshan district, 70 ha, is the largest urban project of post-industrial landscape renewal in Beijing.

[27] Yongding River, a historic regional river and the most extensive water system in Beijing, is forming an essential urban greenway in the city's southwest.

Fig. 8.11 Shougang Industrial Park constructed in the political idea of Sponge City. (Picture by Mengyixin Li, 2018)

city's resilience and signifies an increase in the ability of nature to respond to changes (Li, 2017).

The Sponge City is conducive to producing more green surfaces and structures with the systematic function of ecological performance adapted to uncertain urban changes, connecting the former industrial areas, creating public open spaces in the dense urban fabric, such as the Shougang Industrial Park (Figs. 8.11 and 8.12). This park project lies at the intersection of the extended historical central axis and the western ecological and cultural development zone of Yongding River Greenway. According to the principle of ecological priority, the green network conceived in Beijing Master Plan (2016–2035) embraces Three Hills and Five Gardens Greenway, Yongding River Greenway and Shougang Industrial Park. The landscape ecological park in the Shougang area, as the first C40 Positive Climate Development Project, aims to develop Beijing in a climate-friendly manner, reduce carbon emissions through ventilation corridors, restore industrial wasteland and improve the green space network at a regional scale (Fig. 8.13).

Furthermore, from the perspectives of landscape architects and urban planners, the Chinese compound Shan-Shui, meaning mountains and waters in natural landscapes, has been a consistent ideal pursued in both traditional garden-making and urban landscape conception according to Chinese Fengshui principles. Under the urgent need for large-scale urban constructions, the concept of Shan-Shui City, proposed in 1990 by Chinese scientist Qian Xuesen, became vital, offering a holistic approach to integrated blue-green (Shan-Shui) structure for Chinese landscape architects to explore the new development of planning and design at scales of

Fig. 8.12 Open public space in Shougang Industrial Park. (Mengyixin Li, 2018)

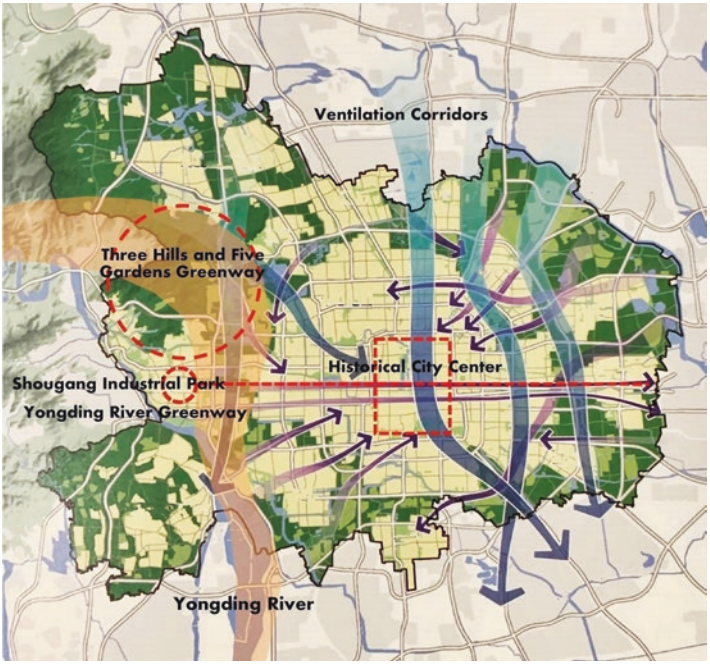

Fig. 8.13 Shougang Industrial Park planned in the network of regional greenways. (Elaboration by the Authors of Beijing Master Plan 2016–2035 2019)

Fig. 8.14 The Shan-shui structure of Beijing ancient city as the root of green open-space development. (2019, Courtesy of Qian Y, Elaboration by the authors)

'architecture-landscape-city' (Wu, 2001). The Shan-Shui structure extracted from Shan-Shui City is considered the key to organizing green structures and flexibly responding to urban changes in the future (Fig. 8.14). Three aspects proposed by landscape architect Hu Jie could interpret the profound connotation of Shan-Shui City. 'Landscape Shan-Shui' is built based on landscape elements as well as their spatial relationships, where 'Ecological Shan-Shui' in terms of green functionalism implies the meaning of green infrastructure in Western countries and 'Humanistic Shan-Shui', influenced by traditional Chinese Shan-Shui cultural and artistic images, helps to establish the harmony between man and nature. In conclusion, the Beijing greenways can re-connect the cultural heritages in the form of historic parks or gardens with unique landscape images, integrate natural landscape resources in urban and rural areas, perfect the traditional Shan-Shui structure and play an ecological role open to the future for people's health and their better life.

Compared with Milan, Beijing greenways construction started late, yet has undergone constant development. In 2012, taking the urban fitness paths of the

Olympic Forest Park[28] and Nanhaizi Country Park[29] as prototypes, the concept of 'Healthy Greenway' was put forward by the administration. Influenced by the healthy city, the greenway is explored as a linear green channel that can realize four functions: green commuting, leisure and fitness, history and culture and urban–rural integration. Beijing later completed two pilot projects, 'Chaobai River Greenway'[30] and 'Yingcheng Capital Waterfront Greenway',[31] focusing on the sustainable management of water resources in the idea of Sponge City and the practical construction of waterfront pedestrian and bicycle paths. In 2013, Beijing Municipal Greenway Construction Overall Plan (2013–2017) was officially promulgated. The plan proposed building a dynamic greenway system of more than 1000 km within five years, providing diverse green leisure and recreational spaces to meet people's various needs. In 2015, the II Ring Road Greenway (87 km long) was constructed and combined with more than 20 parks and cultural relics, such as the Temple of Heaven and the Lama Temple in the Ming Dynasty and waterfront and road green spaces of the moat. This essential inner-city green circle also realizes the enhancement of ecological landscape functions and leisure service functions.

According to the Beijing Master plan (2016–2035), the green fabric in the background of Shan-Shui City is intertwined with the Beijing Ring-road system, planned park rings and forestation, growing to form an organic whole. By 2018, the quantity of Beijing greenways had grown considerably within the conceptual spatial distribution of 'Three Rings, Three Axes, Multiple Corridors'. The green emergence makes citizens feel a sense of contentment and happiness during walking or cycling, especially during the period of the Covid-19 pandemic. Some greenways, such as the Three Hills and Five Gardens, the Beijing Garden Expo Park and the Yongding River, are pivotal for connecting existing Shan-Shui structures and landscape elements, historical gardens, country parks and open green spaces at multiple scales.

8.3.2 Beijing Greenways Projects for New Development

Beijing greenways have a new development tendency, extensively influenced by the reshaping of greenways as structures for urban changes on derelict industrial sites in Western countries. Researchers and government officials are increasingly seeing these abandoned land-regeneration projects' tremendous impact and potential,

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[28] Olympic Forest Park, 680 ha, as an 'axis to nature', is one of the largest urban parks in Beijing.

[29] Nanhaizi Country Park, 1100 ha, is one of Beijing's four major country parks and the most significant wetland park.

[30] Chaobai River Greenway (30 km long) in the ecological forest landscape belt, regarded as a new urban landscape greening model, is the first attempt to build Beijing greenways along natural corridors, landscape roads and linear green open spaces to maintain the ecological balance of land, reduce PM 2.5 and realize green travel to alleviate traffic congestion.

[31] Yingcheng Captial Waterfront Greenway (9,3 km long) in the traditional cultural landscape belt of the inner city complements the II Ring Road Greenway system around the historical moat.

Fig. 8.15 Beijing Zhangjiakou Railway Green Corridor in the urban green fabric between the II and V Ring Roads. (2018, Courtesy of Qian Y, Wu D; Elaboration by the authors)

making them ambitious. Some new attempts resulted. In the program 'Beijing Greenway 2020',[32] the Beijing Zhangjiakou Railway Green Corridor[33] within the network of Three Hills and Five Gardens Greenway was discussed in depth. For the 2022 Beijing Winter Olympics, the newly built Beijing Zhangjiakou high-speed railway will pass through the original line and the discarded part of the railway will be reactivated inside the North Fifth Ring Road, from Bajia Country Park to Beijingbei Railway Station (Fig. 8.15). Under the university's influence of the research program, an international design competition for the historical railway landscape renewal named the Beijing Zhangjiakou Railway Heritage Park was held in 2019, attracting distinguished design companies' participation.[34] In each design scheme proposal, the planned Beijing Zhangjiakou Railway Heritage Park was conceived as a resilient greenway of slow traffic, recreation and sports for everyday urban activities. This park could also become a place for people to recognize and experience the urban culture, bringing more business opportunities to surrounding areas to enhance the vitality of the whole community (Fig. 8.15). More importantly, the large-scale park as green infrastructure plays a crucial role in climate regulation,

[32] The landscape architectural research team launched this research program for urban green renewal at Beijing Forestry University in 2016.

[33] Beijing Zhangjiakou Railway, the first railway designed and built by the Chinese, extended from the northwestern suburbs to the Beijing city centre.

[34] Agence Ter, Nikken Sekkei Ltd, Miralles Tagliabue EMBT, Tom Leader Studio Inc., China Academy of Urban Planning and Design and China Architecture Design and Research Group.

rain and flood management in the idea of Sponge City, the construction of biological habitats and migration corridors and biodiversity protection.

Another typical greenway project for new development is the Shougang Industrial Park. This park presents a mix of built and green spaces to be recovered inside the functional core area of the Capital and will show the integrated landscape features of both industrial heritage and nature. By combing abundant natural mountain-water resources, such as the Yongding River, Shijingshan Hill and Three Hills and Five Gardens within the traditional Shan-Shui structure, this landscape ecological park is rebuilt according to the north-south landscape axis to improve the green space network of Beijing's urban parks at the regional level. It also becomes an urban regeneration and restoration project under the guidance of top-down ecological ideas. In its preliminary planning, the Beijing Municipal Institute of City Planning and Design and the Shougang Group jointly formulated a comprehensive low-carbon urban development and innovative ecological plan. Under the concept of ecologically sustainable development, the project aims to prove that towns could develop in a climate-friendly manner and reduce carbon emissions. Elements such as green buildings, clean energy, waste management, water resources, green space and industrial sites have become essential in renovating the derelict industrial areas.

8.4 Conclusions

Milan is now one of the greenest cities in Europe, having transformed all its derelict industrial areas into public parks connecting agriculture, river basins and leisure open spaces. The transformation of the Milanese urban fabric followed economic reasons and market dynamics and was driven by a lack of ideas from the Administration that, on the one hand, produced an abundance of research by the academics (administrators asked the university researchers for several analyses and project proposals about the future scenarios of Milanese abandoned areas) and, on the other hand, blocked any development of these derelict areas, which were preserved in a state of limbo. Only recently, with the approval of the General Master Plan (2012), most of the ideas and contributions developed during the last decades were included in the urban plans. The planning departments are now operating to protect all the post-industrial areas, scheduling their conversion into public green areas connected by slow mobility and devoted to reforestation.

Compared with Milan, Beijing is still in the process of rapid urban development where industrialization and de-industrialization coexist. It means that the city presents a complex urban collage with characteristics of historical, in-use, and obsolete aspects that are difficult to manage. It also indicates that there is enough room left for the green transformation of derelict industrial areas, which prompts researchers and designers to devote more energy to exploring this new topic for urban future development. Most greenway plans and their implementation reflect the organizational strategy of Sponge City and the traditional philosophy of Shan-Shui City for reshaping the city–nature relationship and integrated green network. Nevertheless, facing the initial stage of green conversion, the fragmented appearance of green open spaces is still worth pondering. The regeneration of post-industrial sites from abandoned areas to life-show belts may be a new sustainable land development method and a multi-layered urban landscape formation, just as the explorations experienced by European and American countries.

We can observe that the 'immobility' of the governance in Milan is better than any wrong choice. In parallel with that, we can also find that the 'ambitiousness' of Beijing municipality, which has proactively launched plans and measures for Beijing green city development in different stages, manifests inclusiveness that implies the full acceptance of the Western greenway concept and its multifaceted redevelopment for a new era.

However, what emerges is also that political and strategical indecisions may bring scientists to propose and disseminate ideas and projects that can influence politicians and the citizens, creating new expectations and close attention to sustainability and resilience.

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Chapter 9
Landscape, Infrastructure, and Aesthetic Dimension: Methodological Strategy for a Medium-Sized Brazilian City

Luciana Bongiovanni Martins Schenk

Abstract This chapter presents a process of planning and design that has been developed for São Carlos, a medium-sized city in the state of São Paulo, Brazil. This process is accomplished based on the potential relationship between the fields of knowledge of green infrastructure and landscape architecture. This work sought to answer contemporary questions related to the value of infrastructure and its alignment with global and local values and quality of life issues. Moreover, it looked for solutions related to the culture and the community of São Carlos. The approach was based on the strategies suggested via green infrastructure advocates and was used in the working process, testing the interrelations of technical responses with the places of intervention. Through the development of the work, it was possible to ascertain the role played by aesthetic and cultural dimensions while designing the proposal. This argument is presented in the first part of this text, which reestablishes the contact and relationship of the pioneers of the field of landscape architecture with the Arts. The second part presents the methodological strategies that structure the planning and design developed by the group. The drawing process attempted to associate technical, social, cultural, and aesthetic subjects: a proposal for a landscape experience formulated in contact with reality. The proposal synthesizes information and demands gathered by an interdisciplinary team and includes investigations of documents, as well as the contact with community leaders. The formal result is a key addition to the debates held with the community and in the formulation of public policies that endeavor to ensure the construction and maintenance of the plan and its design. This article seeks to demonstrate how green infrastructure and landscape architecture can be related strategically in contemporary production of places.

Keywords Landscape Architecture · Green Infrastructure · Green System · Organic Principle · São Carlos

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9.1 Introduction – Landscape, Infrastructure, and Landscape Architecture

Landscape is a polysemic term and is part of the production of artists, literates, poets, biologists, ecologists, geographers, and architects (Besse, 2014). Among the many fields and disciplines that have the landscape as their object of study, this text will discuss the one of the landscape architect.

The many understandings of landscape, the aforementioned polysemy, allow each of the previously distinguished fields to construct the meanings related to their background; in other words, the landscape of the ecologist is not the same one of the artist, nor that of the geographer, which in turn differs from that of the sociologist. The landscape architect, when developing plans and designs, drifts between inputs and perceptions; their production is driven by the synthesis of those pieces of information and is the result of this abundance of approaches: of a geographical, ecological and biological, political and social, and cultural and aesthetic framework. The expected response of this is a design that materializes in the form of a representation: the drawing of this future landscape. This proposal could be developed from different scales, from regional to urban, or from an urban design to particular places.

From planning to design, this development is enriched by a look that views the landscape through its subjective and objective dimensions due to the professional's education and training since the origins of the profession evidenced by its pioneers.

The qualities present in the landscape lead us to stand up for its necessary representation in the process of contemporary planning and design. The development of this writing is in line with authors who claim the landscape to be a complex relationship between nature and culture (Berque, 2016; Silvestre & Aliata, 2001). The richness of the landscape, in terms of meaning, arises from intertwining different perspectives with a subtle perception of what is presented as experience. The result of this intertwining dialogues with the artistic, aesthetic, and both private and collective cultural fields.

Further, since the last decades of the last century, urban planning has drawn on the contemporary guidelines of sustainability and resilience, introducing new prerogatives to the principles that should guide its actions.

The emergence of what is known as "green infrastructure" presented as network interventions, made use of technical devices and typologies, and accumulated analysis in the processes of the impact generated by urban occupation, e.g., evaluations based on indicators. The introduction of ideas related to ecosystem services as a possibility to value projects and areas witnesses an effort to develop a more pragmatic environmental approach.

Despite its definition still being in development (Mell, 2010), the consideration that green infrastructure can operate as a strategy that accommodates multiple environmental and human approaches and dimensions is consolidated among authors. According to these authors, this quality contributes to diminishing the conflict between nature and development caused by the occupation processes (Benedict & McMahon, 2006; Ahern, 2012; Mell, 2010, Santa'Anna, 2020).

However, the related actions do not include subjective, aesthetic, and artistic dimensions.

> Before this background, the concept of green infrastructure and green infrastructure planning provides a pragmatic working method to preserve and develop green spaces well-grounded on their functions for human well-being. Aesthetics, however, is the weak point of the method. (Hauck and Czechowski, 2014, p.21).

This writing aims to explore these qualities and proposes a necessary link between Green Infrastructure and Landscape Architecture, based on the example of a Brazilian city, to establish methodological alternatives so that the landscape, in all its complexities, is recaptured as an inalienable part of the planning process. The chapter states the landscape as a place capable of bringing together physical and metaphysical as well as quantitative and qualitative approaches, the place of life in its many dimensions.

9.2 Landscape, Aesthetics, and History. A Turning Point: Frederick Law Olmsted

One of the most prominent pioneers of Landscape Architecture, Frederick Law Olmsted, laid down in his writings and work the genesis of the professional field. The landscape, materialized in his plans and designs, connects in a complex way the technical and aesthetic, as well as the social, cultural, and political dimensions of the city.

In his project for Central Park in New York, developed in partnership with Calvert Vaux in the middle of the nineteenth century, technical solutions for draining urban waters and safeguarding springs were associated with a large green area. This generous portion of nature in the middle of the city, 800 acres of land, would offer the opportunity for rest, contemplation and social gathering (Olmsted Jr. & Kimball, 1928, pp. 92–95; McLaughlin ed., 1983, p. 119). The argument in Olmsted's writings about the need for such places in the city had a fundamental political dimension, seeing the park as a debt owed by the municipality to its citizens (Roper, 1973, p. 317).

In the original proposition for the park, technical solutions solved infrastructure issues: by excavating the area, the project built both the new Manhattan water reservoir and modeled the relief and its landscape, changing the perception of paths and creating bridges and underground passages. This action, in particular, prevented the streets and avenues that cross the park from impeding the pedestrian's visual continuity. Visual continuity of the landscape was a central question for the picturesque theorists. Olmsted had among his books Treatises by Uverdale Price – On the Picturesque, 1794, and William Gilpin – Observations, Relative Chiefly to Picturesque Beauty, 1772 (Mumford, 1955, p.72).

The visual continuity of the landscape was a value to be preserved, as it allowed the enjoyment of this uninterrupted aesthetic experience. In the same way, the water reservoir took the form of a lake in a carefully picturesque design, making use of what the treatises claimed to be fundamental to the green open spaces: visual continuity, variation, mixture, and surprise.

The quality of his way as a pioneer of Landscape Architecture – a precursor to the idea of urban planning through a system of parks and wooded streets that shape a landscape in harmony with nature and its logics – is witnessed by authors and historiography, for example (Dal Co et al., 1975, pp.168–170; Spirn, 1995, pp. 164–165). What is intended to be related to this process is a vital issue present in Olmsted's interests and writings: planning and designing a system is not just a technical matter; in its aesthetic and cultural dimension, the elaborated system has as its creation parameter the organic principle (Fischer, 1976, p. 30).

From this aesthetic principle, a physical and metaphysical matrix developed the idea that the place of intervention has its own physiognomy and qualities that must be perceived, highlighted, and revealed. In this way, the changes proposed by the planning and design visualize potentialities, translating them and materializing them into new experiences. These experiences, for Olmsted, also have explicit pedagogical and subjective dimensions (Schenk, 2008, pp. 121–125).

Perhaps the most paradigmatic example of this complexity is the Emerald Necklace in the city of Boston. There, the landscape differs greatly from the one which had been used as a formal proposition in Central Park. According to the characteristics of the marshy area round the Muddy River, the vegetation had a more wild appearance, and the presence of the swamp would not be erased by the proposed park system; on the contrary, expanding the register of the dominant cultural values of the time, the designer would celebrate through his writings: the swamp is as beautiful as marble (Creese, 1985, p. 175).

Two ideas are presented here: one of a designer concerned with the qualities and logic of physical nature for which he plans and designs and the other the perspective that in order to carry out this design, there is a fundamental contact with artistic fields. The articulation between these two ideas is based on the organic principle: "a project should be locally congruent and appropriate to the original conditions of the site" (Fisher, 1976, p.31).

Regarding the development of Olmsted's work, it is possible to observe the maturation of the idea of a system that had already been inaugurated in Europe in interventions implemented in large capitals in the middle of the nineteenth century, such as the Paris of Haussmann and Alphand, or in cities that rehearsed this greatness, such as Barcelona in Cerdá's plan (Benévolo, 1978). Olmsted had contact with interventions like these, but with a special focus on the system of green open spaces, in his writings and plans, he deepened a dialogue between technical, social, artistic, cultural, and political issues.

In relation to infrastructure, he formulated spatial planning by articulating free and permeable spaces responsible for the drainage and retention of water. Urban reforestation also played an important role in supporting connective networks: they were called parkways when related to streets and avenues and received special attention in his writings in relation to the aesthetic and wholesome quality of the system. Olmsted's argument focused on how these actions which built the system materialized in the urban territory, here the form, forged by the organic principle and within the aesthetic precepts of the Picturesque, constituted the opportunity to transform a technical action into a memorable experience, a solution impregnated with metaphysical meanings.

9.3 Another Turning Point: Ian McHarg

The disciplinary field of landscape architecture has maintained throughout its development since its foundation at the beginning of the last century, the aforementioned articulation between technique and aesthetics, updating itself over time due to developments on the technical, technological, and artistic fields. The departure from the picturesque ideals and the alignment with the modernist vanguard occurred over years of criticism, quest, and aesthetic experimentation (Tunnard, 1938; Trieb, 1993; Walker & Simo, 1994), until the emergence of a new technological perspective leveraged by the post-war period.

With the introduction and diffusion of the computer in the 1960s, the perspective of planning by relating different types of information transformed the approach of the landscape architecture field (McHarg, 1969). Taking hydrographic basins as a planning unit, a perspective originally taken from the field of American Regional Planning, McHarg and his team of researchers started to develop an analysis that crossed data and information, revealing weaknesses and potentialities of the territory and its landscapes. The synthesis of these cartographies distinguished areas suitable for different uses, in such a way as to reduce the conflicts generated by the process of human occupation and the environment through adequate planning.

> Before this background, the concept of green infrastructure "McHarg was able to define the task of landscape architects in a more comprehensive way. (…) It is the assignment of a landscape architect to actively manage *land use* in accordance with the natural circumstances. Spatial development (settling, transport, and economy) is not primarily based on economic interests, but on nature conceived as "interacting process, responsive to laws, constituting a value system, offering intrinsic opportunities and limitations to human uses" McHarg, 1969, p. 55. (Hauck & Czechowski ed., 2014, p. 12).

Design with Nature is a book that references the breadth of development and planning processes, and its author Ian McHarg was a great source of inspiration and reference for future generations, not only of landscape architecture but also of landscape ecology and contemporary planning.

The preface to McHarg's book, written by Lewis Mumford in 1969, presents an argument that reverberates the questions established by Mumford in relation to Olmsted in his 1955 book, *The Brown Decades*: the idea that the project executed in congruence with nature has a pedagogical, formative, and potentially revolutionary dimension. Based on this perspective, landscape design can be perceived as a creative opportunity to transform not only the landscape itself but the world as a whole.

It is also important to reveal another network of contacts that ends up illuminating McHarg's path and his alignment with the continuity of the Picturesque, the aesthetic precepts of the formal solutions that materialized in planned and designed landscapes by McHarg. The proposals were however rendered as anachronistic in the end of the last century (Corner, 1999, p. 8).

Seen from a distance, this dissonance between form (picturesque, historical, and traditional) and methodological approach (scientific, revolutionary, and modern) can create new interpretations. It seems necessary to develop some mediation in order to inscribe Ian McHarg's investigation within a context, understanding his design action not as a dated representation but rather as a possible answer within that historical moment in which scientific research was transformed by computers.

Delving into what moves these theorists and designers, it is possible to identify their regard for the gathering of information about the characteristics of a place. The values and principles present in McHarg's writings, as well as the scenarios presented as proposals for occupation, endorse this attention to the qualities of nature present in the territories, their flows, and phenomena: the design intends to keep them and make them more visible. In the same way, it is possible to observe the presence of cartographies in which the privileged views are marked, as well as the memorable places to be maintained due to their aesthetic qualities. This action denotes appreciation for the subjective and metaphysical qualities that constitute the landscape. The design cares in the insertion of new occupations, which propose implementations that do not corrupt the original landscape. The physiognomy of the memorable landscape, the identity of the place, was a value to be preserved.

In his manifestations in the media of the time, McHarg denounced the losses caused by disastrous occupations that resulted in conflicts and the meanings of a development executed only based on economic principles. His writings and professional practice sought to present alternatives, anticipating contemporary issues related to environment, territories, and their landscapes.

The research carried out on new technological bases would make the field linked to landscape ecology flourish. Ian McHarg's methodology made it possible to visualize the complexity of the layered territories, also the produced synthesis constituted a strategy through which were pointed out the areas that could be occupied because they caused the least impact on the environment, or, on the contrary, areas that should be safeguarded from the process of occupation.

The context in which McHarg writes is immersed in Modernity, as well as its keys for interpreting reality. His challenge is still the search for a meaning inscribed in generalization processes peculiar to that historical moment. The possibility of building a synthesis map that highlighted the places that could and those that should not be occupied is itself an enormous advance. This process, which generalizes information, has its own risks and rewards, as generalization tends to blur the particularities. This tendency will be subject to criticism carried out in the present to all Modernity.

However, there seems to be an antidote to this generalization inscribed in McHarg's working process: a look at the phenomenon, the place, something that supports the approach of the landscape architecture discipline since its origin. It is precisely through the multiscale approach present in the method that Ian McHarg can be aware of the particularities. Moving from the cartography to the design of places and possible scenarios, the desired spatial quality for the projected place is presented: the proposal and how it appears intended to materializes the future experience trough the represented images.

The criticism focuses on the picturesque aspect that the representations have in McHarg's projects; however, according to the author's perspective, it presented a drawing committed to the intrinsic qualities of the place: the landscape and its qualities of experience are the aesthetic issue to be achieved. The horizon is to maintain the identity and quality of the place, as they are fundamental values to the act of designing (Herrington, 2010, p.16).

What is important is to retain both Olmsted's and McHarg's actions, when planning and designing landscapes, is the necessary participation of the artistic field. The forms presented in the design can be the object of criticism; in fact, art lends itself to this action. However, facing this shift of scales between the plan and the design requires a form. For both landscape architects, the form presented in projects was the result of contact with the place trough art: landscape, art and culture in different contexts, Nature as a source, parameter, and inspiration. This question is placed again in the present: what Nature is this? To which is the design developed? Which are the possible landscapes?

In recovering these contributions, one tries to confirm through these two pioneers of landscape architecture, separated by almost a century, the necessary articulation between technical solutions and the aesthetic dimension that the design assumes in the construction of territories and landscapes.

9.4 Green Infrastructure

> Green infrastructure planning is based on the identification of areas that supply relevant ecosystem services and then tying these valuable areas into a network to accumulate these services. (…). Areas are selected because of their utility and their position related to other areas. Hauck & Czechowski, 2014, pp. 20–21).

Since the beginning of the new millennium, the literature on green infrastructure has undergone a change witnessed by different authors (Mell, 2010, p 23). Its strategies have been leading the planning processes and overcoming barriers, as much for its principles, such as, preservation, construction, and connection of habitats in urban green spaces, as well as for the possibility of being associated with existing infrastructures known as "gray infrastructure."

The objective of the strategy of planning with green infrastructure is to form a network of spaces, which are apt to perform ecosystem services. Its implementation requires the establishment of active relationships between these places that function as knots of this network, reducing conflicts caused by the process of human occupation in relation to the environment and promoting life.

Among the goals of this network are the recuperation of the drainage natural system; improvement in temperature and air quality control, with the consequent increase in urban resilience related to climate change; and the improvement in the health and life of the population. This is materialized through the presence of permeable areas, urban reforestation, and a special attention paid to water bodies and their floodplains, rivers, and streams present in urban sites.

It is a very pragmatic working method that has been leading publications and gaining authors. For the territories yet to be occupied, there is now a wealth of literature on how the planning strategy can be addressed, although there is a point of weakness shared by several authors with regard to aesthetic issues: the typology of a green infrastructure network is not enough; it is also important to know how it is disposed, what quality of experience this network has, and how it can be promoted.

Multidisciplinary planning and work strategies contemplate different contributions, including artistic ones, frequently considered as a minor issue, or narrowed within a functionalist perspective.

A major challenge, especially for realities like the Brazilian one, regards not only the consolidated cities, huge metropolises like São Paulo with almost 20 million inhabitants, but also smaller cities, whose development process followed the model of metropolises, by channeling their streams and waterproofing their floodplains, occupying the territory neglecting the green open spaces and urban reforestation. These cities suffer from flooding problems and a lack of places for leisure, health, and education. The idea of developing a system, a network of green infrastructure, is still a remote reality, culturally and politically, for most of the 5570 Brazilian municipalities. As of July 1, 2020, the population of Brazil reached 211.8 million inhabitants. Approximately 85% of the population lives in cities (IBGE, 2020). Although there is the figure of the Director Plan (a plan for land use including city and rural areas) institutionally constituted for cities with more than 20 thousand inhabitants, in practice the planning processes are linked to departments of different functions, education, health, transportation, and environment, whereas in most of the cases, there is no planning department that promotes effectiveness to the actions.

Taking as an example a medium-sized city in the state of São Paulo, the city of São Carlos had its Plano Diretor approved in 2005 and revised in 2016. There is no guideline or remarks about the establishment of a system of free open spaces or any strategic approach according to the principles of green infrastructure.

The guiding principle is, to this day, zoning by activities and urban land use indicators, frontage, and permeability. For the new areas, there is an advance with guidelines for the installation of rainwater retention in the lots, but for the consolidated and waterproofed areas, the proposals presented are elaborated within the procedures of gray infrastructure: pipes, tubes, galleries, and retention walls.

9.5 São Carlos: History, Processes, and Landscapes (Fig. 9.1)

The city of São Carlos was founded in the middle of the nineteenth century, and its development was linked to the economic cycle of coffee production, which characterized the process of occupation of the state of São Paulo. Structured on orthogonal streets on a rugged relief, the grid morphology is interrupted by the passage of the

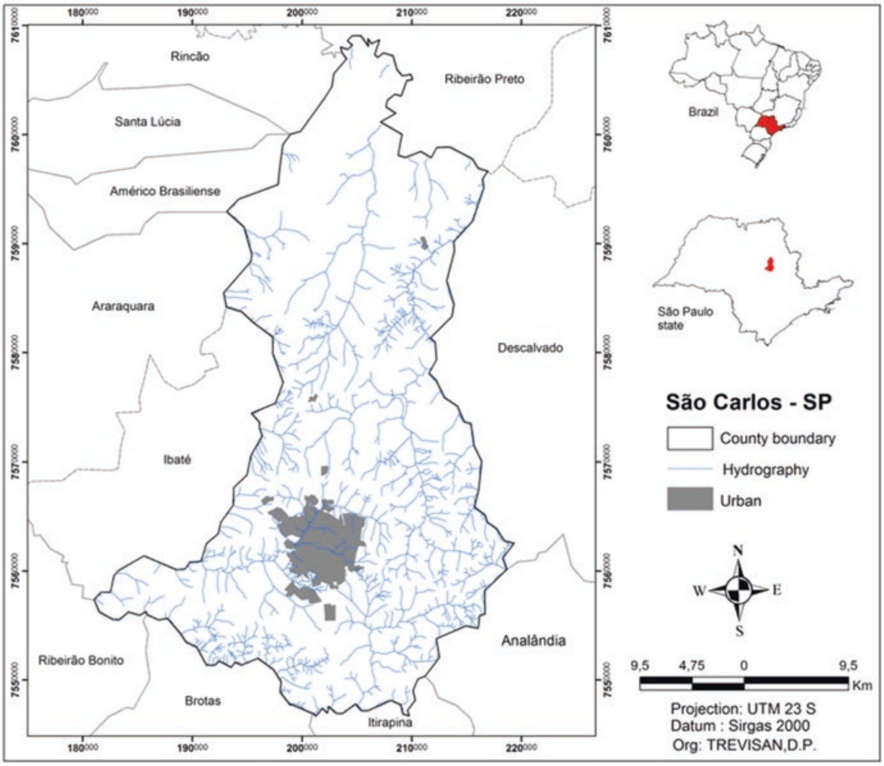

Fig. 9.1 The map localization of São Carlos municipality. (Diego Trevisan, 2015)

existing streams in their natural landscape. The arrival of the railroad coincided with increased immigration from Europe, extending the available manpower to work in the coffee plantations accelerating its growth. As a consequence, the city's population grew, and with the industrialization process and increase in services and commerce, it became a center of the region.

Public universities were also founded, underpinning an educational pole of national reference. The University of São Paulo (USP) and the Federal University of São Carlos (UFSCar) were established with courses dedicated to the fields of technological research.

Nowadays, the city has 255,000 inhabitants and occupies approximately 6% of the municipality's territory. In its territory, there is the presence of a dense water network, fertile soil, and few remnants of the original vegetation. Most of the land, with the exception of those areas protected by environmental laws, is used as pastures, eucalyptus, and sugar cane plantations. The central area of São Carlos also illustrates a historically significant lack of effective drainage leading to ongoing problems. These problems were aggravated due to the growth process, occupation of the floodplains, suppression of vegetation, channeling of streams, and waterproofing of urban territory. Periodic rainfall and the excessive volumes of water associated with it have increased in the context of climate change leading to more dramatic floods being visible over shorter periods. This climatic and urban development context thus generates increased debates between the population and its government, including legal actions by the Public Prosecutor's Office demanding alternatives, plans, and projects to avoid these events in the city center (Figs. 9.2, 9.3, 9.4, and 9.5).

The Working Group for The Urban Parks of São Carlos (GTPU) was established based on the initiative of the Municipal Council for Development and Environment, and it has participation from professors at the Universities of São Paulo and Federal University of São Carlos and their undergraduate and graduate students. The group's objective was to offer, through theoretical and practical research, alternatives for the development process of the city and its municipality. The creation of the GTPU coincides with a 2017 municipal decree that selected seven areas to become future parks. A working group was created to connect the parks to the existing city and to assist in the elaboration of programs and project development. The confluence of

Fig. 9.2 The first known cartography of the city (São Carlos Pro- Memory Foundation, undated)

Fig. 9.3 The structuring axis of the city: São Carlos Avenue, in the valley, is the Gregório Stream. (Luciana Schenk, 2015)

Fig. 9.4 Image Channelization of Gregório Stream, mid-twentieth century, main water body in the Gregório Basin, center of São Carlos city. (São Carlos Pro-Memory Foundation, undated)

Fig. 9.5 Images from floods in the center of the city in the last century. (São Carlos Pro-Memory Foundation, undated)

professors from different backgrounds created an interdisciplinary space for debate and research. The group saw in this demand the opportunity to set the city's open spaces in a contemporary agenda linked to green infrastructure.

In Brazil urban drainage issues are still settled on assumptions of gray infrastructure: channeling and covering the streams and conducting water by the shortest way outside the city. The principles that nourish the GTPU, on the contrary, are based on values generated by the discipline of Landscape Architecture that gain fresh impetus from the development of precepts to contemporary research and practice such as Green Infrastructure and Nature-based Solutions (NbS).

Planning and designing in a context such as that of Brazilian cities are, first of all, to understand the need for setting up a path for the coexistence of different techniques and to overcome the prejudice against green solutions. Therefore, there is a need to establish emblematic places and, at the same time, initiate an effort to change a culture: new and positive urban experiences linked to nature and its memorable landscapes; bringing this perspective into practice is to achieve, as citizens, health quality and greater social interaction. Alongside these benefits is the establishment of a city agenda planning for resilience and adaptation to climate change and for quality of life, in its most diverse manifestations.

One of the methodological strategies developed by the GTPU is the construction of cartographies inspired by the studies of Ian McHarg. They are the gathering of different cartographies through geoprocessing, which allows the crossing of data and generation of information. This updating of the methodology inaugurated in the 1960s occurred already in other fields of knowledge in relation to cities, deepening processes of understanding the urban territory, which can subsidize the development of plans, public policies, programs, and projects.

The image in the following cartography is the synthesis of the gathering of different cartographies, such as those of hydrography, relief, free public leisure areas, environmental protection areas guaranteed by law, and urban perimeter. The blank areas are the unqualified free areas that were destined for future parks by the Municipal Decree of 2017 (Fig. 9.6).

Fig. 9.6 Image of the complex cartography: synthesis of cartographies of the urban space of the city of São Carlos. In blue, Gregório Basin is highlighted (Schenk, 2021)

This cartography sought to build a representation that gathered significant open spaces for the establishment of a system that could configure a network of green infrastructure in the city. The actions visible in these areas can potentially be included in the planning process. Strategically at this point, the aim is to unite spaces that are public or that, even being private, must remain free, without any occupying buildings, as they are protected by Law. All of these issues were present in the debates of the GTPU when flooding devastated the city center in November 2020 due to very heavy rain in a short period of time (Fig. 9.7).

9.6 Research, Plan, Design: Possible Scenarios for a Resilient Basin

The workshop lasted over 2 weeks, between January and February 2021, with a 3 week for the post-production of images. It was attended by 15 people, including students and professors. The scope of the study was the Simeão stream basin, since according to the information gathered, its waters and its current channeling situation were responsible for flooding of November 2020.

The first action was the process of knowing the territory that brought together objective contributions such as the collection of census data and geoprocessing to characterize the area. The basin includes areas of commercial use of the land downstream, residential and mixed-use areas in its middle portion, and residential and industrial uses upstream. There are markers of social and environmental vulnerabilities throughout the basin with the presence of a population of low education and income.

The railroad – currently transporting only cargo – crosses the city and is a striking presence, dividing the basin into two unequal areas. The street structure follows the pattern present in most Brazilian cities, in which the final aspect is a mosaic of juxtaposed pieces, since the process of dividing the lots is carried out mostly by the private sector, often compromising the continuity of streets and fragmenting the urban fabric (Figs. 9.8, 9.9, and 9.10).

The second action of the research was focused on getting to know the basin with a greater degree of proximity. Under normal conditions, this moment of research is called treading the territory and is based on the idea that the frequentization of the place is a necessary condition for the understanding of its qualities. In a research of phenomenological matrices, this walk composes the process of building the intelligibility of a territory based on the body and its experience of the place, combining objective and subjective aspects. There is a fundamental question here articulated by several authors: a practice done by the human body that moves through and is affected by the space, a body that perceives, chooses, draws, photographs, discovers (Careri, 2013; Cauquelin, 2007; Smithson, 1973).

Fig. 9.7 Images of a flood in November 2020: São Carlos center (https://regiaoemdestake.com.br/2018/03/20/sao-carlos-enchentes-voltam-castigar-baixada-do-mercado-municipal-e-outras-regioes; https://obutecodanet.ig.com.br/videos-assustadores-mostram-enchente-que-atingiu-sao-carlos-assista; https://sao-paulo.estadao.com.br/noticias/geral,chuva-intensa-alaga-centro-arrasta-carros-e-causa-estragos-em-sao-carlos,70,003,530,052; https://www.metropoles.com/brasil/videos-enxurrada-arrasta-26-carros-e-destroi-ruas-no-interior-de-sp)

To by-pass the question of the impossibility of carrying out this journey, two alternatives were chosen. The first made use of the remote resource, Google Street View, carried out by most of the group who were not in the city of São Carlos at the time of the workshop, and the second filled in the blanks and bridged the gaps installed by the remote process and the actual place. The latter was named treading with other people's feet. At that moment, with due precautions, the members who went to the field were able to actually have contact with the leaders of the organized community in that territory.

Categories were created based on all the information collected, linking images, and places that constitute the Simeão basin. Along with this process, the participants gathered a reference library, so places were related to reference projects. What works here is not the copy but the relationship; the possible contact between a project that is selected, for different reasons; and the places visited.

After intense debates, at the end of this wide movement of knowing the basin and addressing solutions, a synthesis map was obtained called a Cartography of Wishes.

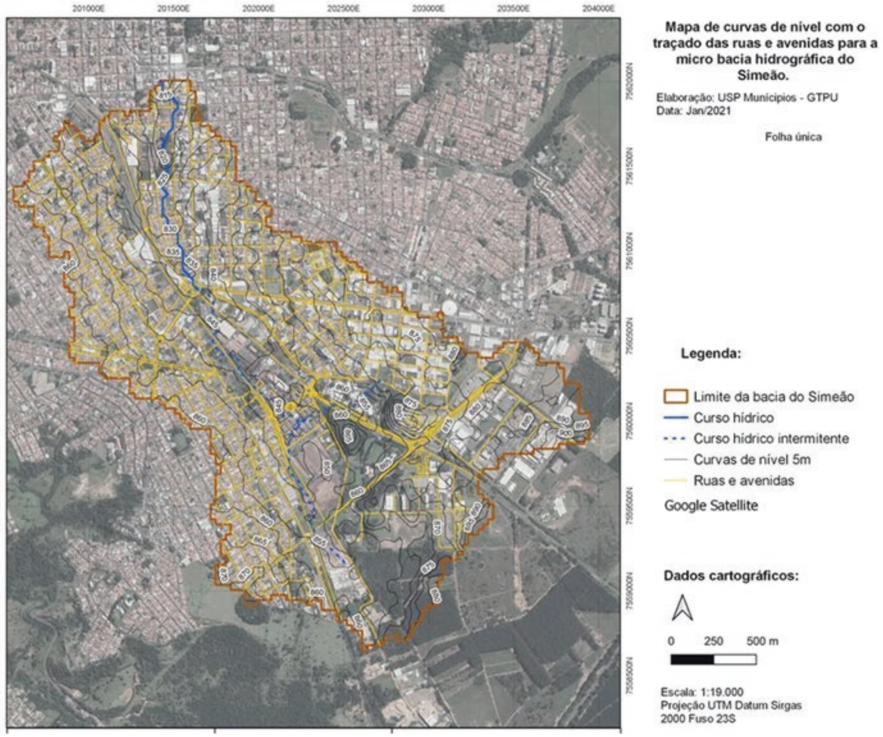

Fig. 9.8 Image of Simeão basin. S. (USP Municípios – Schenk, 2021)

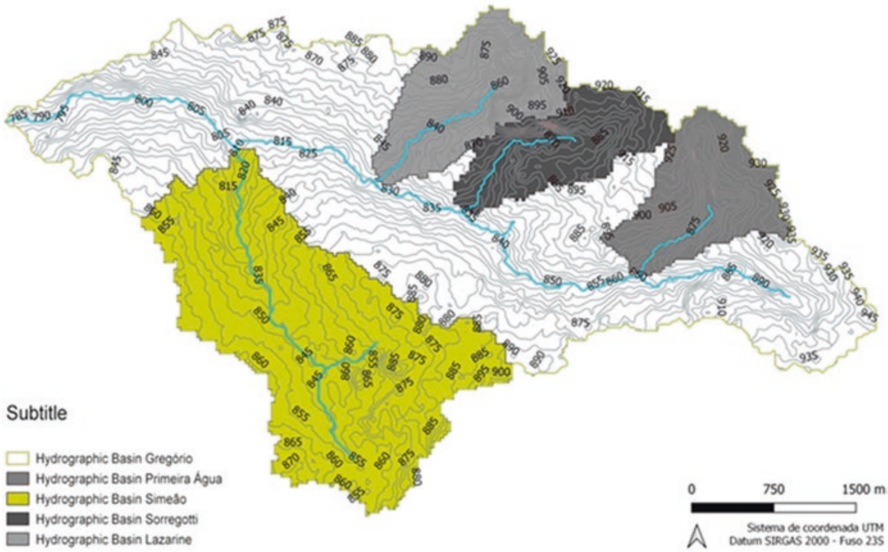

Fig. 9.9 Image of Gregório Basin. In yellow, Simeão basin is highlighted. (Schenk, 2021)

Fig. 9.10 Image of the streets and views of Simeão basin landscape. (USP Municípios – Schenk, 2021)

The plan is configured by means of this technical and sensitive methodology, through the contact of the participants' repertoire and the community leadership, welcoming their suggestions.

The following images show the results achieved during the three intense weeks of work. A system of open spaces that brings together wooded streets, plazas, and parks is proposed for the basin territory. The elaboration of this system is based on the precepts of green infrastructure and is in contact with the reality of the city of São Carlos.

Cartographies of the Simeão basin. Morphology, water network, and relief.

1. The Simeão basin
2. Open public areas: potential system
3. Relief: valleys and watersheds
4. Permeable areas and open spaces
5. The proposal system
6. Highlighted proposal parks.

Several flood water retention systems are considered as technical components to slow down runoff and increase the possibility of rainwater infiltration and, at the same time, articulate open spaces for leisure, gathering, and enjoyment for the population.

The development of the overall project was undertaken based on objective and subjective data. The proposed projects addressed contemporary issues such as flood mitigation and maintenance of water quality, and expansion of urban vegetation, with the consequent decrease in temperature and improvement in air quality. However, what should be emphasized in this process is its cultural and aesthetic dimension and the engagement of the drawings with the images from a cultural repertoire linked to life present in the imagination of the people inhabiting the city.

The proposed forms materialize the places of play, of games, of life in the open air. The proposed representations seek to rescue the brazilian imaginary related to streams before the canalizations, the meanders of the rivers, wooden wharves where fishing and swimming took place, the meeting place with nature, fauna, and flora quite absent from Brazilian cities. The translation of the imaginary into drawings was a rich process whose trigger was precisely the landscape of absence and the little meaning found in the territory.

The answer that is being looked for in this work concerns a repertoire present for most Brazilians: nature is outside the cities, and when nature is manifested in the urban, it has the record of a disaster. Reversing this reasoning is to restore the congruence and reunite with nature on new bases: technical, aesthetic, and ethical ones (Figs. 9.11 and 9.12).

9.7 Conclusion

Landscape architecture is based historically on the relationship between technique and aesthetics and has public life on its horizon. It also contributes to the construction of healthier, more beautiful and fairer cities.

With the development of the disciplinary field, it started to plan landscapes of greater complexity, with strategies aimed at reducing the impacts caused by the process of human occupation and the conflict between development and the environment, without losing its aesthetic dimension.

Techniques and aesthetics change over time but remain associated with an original ethical dimension expressed in the landscape plan and design: a commitment to build convergence between humanity and nature. Every planning and design action is an opportunity to create this fundamental bond, materialized through the landscape, which is the witness of how associating technique and aesthetics contribute to infrastructure issues and promote life. In its most diverse forms, the cultural and aesthetic dimensions are a fundamental part in this process.

The planning and design, undertaken for the city of São Carlos, sought to elaborate a system of open spaces, updating the disciplinary field by its contact with the Brazilian reality and using the strategies of green infrastructure, resulting in a proposal that articulates places with the imaginary, giving rise to new landscapes.

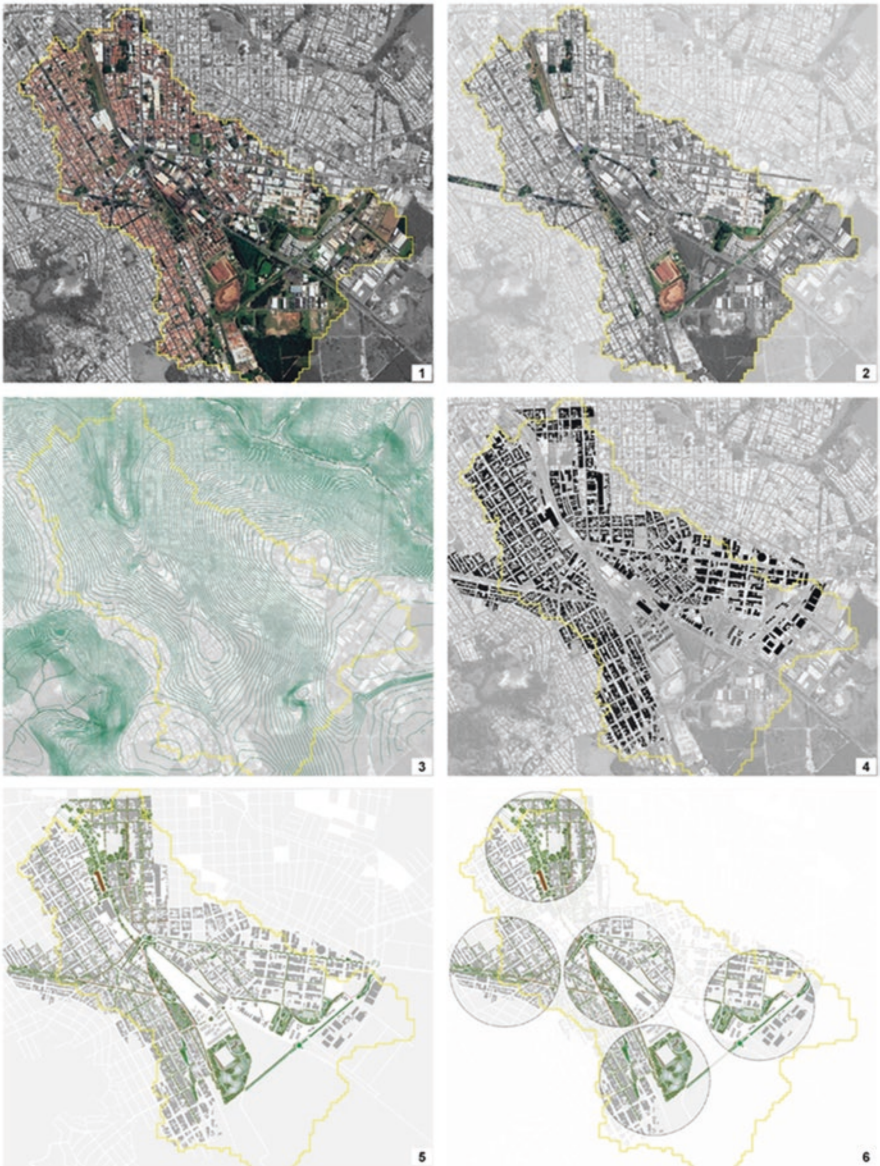

Fig. 9.11 Images produced at the 2021 Simeão Basin workshop. Simeão Basin and the proposed free space system. (Schenk, 2021)

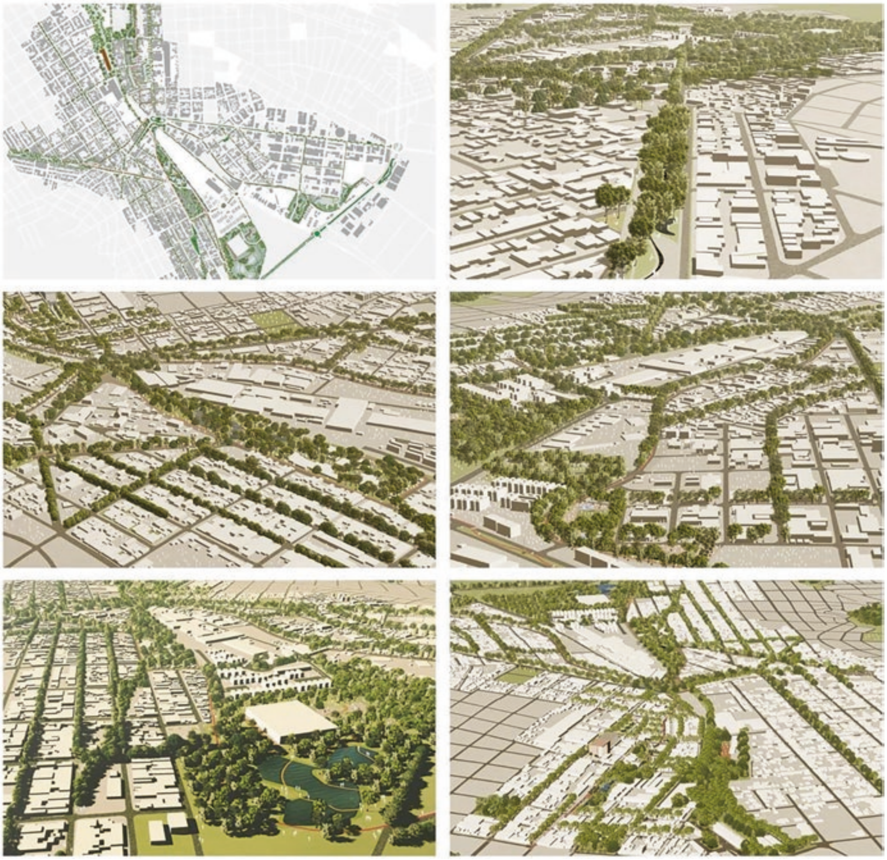

Fig. 9.12 Images produced at the 2021 Simeão Basin workshop. Simeão Basin and the proposed open space system. (Schenk, 2021)

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Chapter 10
Green Infrastructure as Heritage

Réka Ildikó Nagy Báthoryné and István Valánszki

Abstract Although green infrastructure raises more likely issues of ecosystem services, its heritage value as Cultural Ecosystem Services (CES [1] [VI2]) is also acknowledged as imprint of our past, which covers tangible and also intangible elements, such as objects, places, memories, that contribute to the survival of the communities. The interpretation and perception of cultural heritage differ according to the sociocultural background of individuals. Further, heritage always changes, because societies constantly reappraise it. However, the history of urban green infrastructure is always parallel with its settlements. The traditional ways how communities are attached to green spaces could be determined by the geographical and national positions of the particular urban landscape that set the natural, social, economic, and cultural framework of urban green infrastructure (UGI). Although the Japanese Sakura Feats, Hanami is one of the most well-known immaterial green heritage, most of the green heritage has a material sense and connected to a specific urban space. such as historic parks and gardens, historic cemeteries, urban forests, and alleys. Particular elements within the UGI network are the individual trees with a high heritage value. There are three structural types of urban green spaces. Namely, areas, linear elements, and so-called green objects, classified by one's morphology, possibly creating a joint network of green infrastructure. The heritage in GI is a complex and tinged issue, which not exclusively refers to historic nor to cultural phenomena but is well rooted in the past and, in the meantime, gives alternatives to the future. UGI, as a part of the urban landscape, is highly influenced by change because of its strong and fundamental relation to living organisms and ecosystems. Present international understanding of heritage in GI is reflecting a merged approach

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by identifying living or reviving traditions connected to urban greenscape as well as detecting specific urban green spaces with a heritage value. Due to the scope of investigation, we can approach urban green heritage in a different manner. But, in all scales, the approach of work includes common steps – a historical survey as a base, an identification of the heritage values, and a proposal package of protecting and managing the values detected. The chapter goes through different scopes to deep-dive into specific characteristics of urban green heritage as well as management toolkits detached to varying scales, shown by international examples [3].

Keywords Heritage · Cultural ecosystem services · Public participation · Heritage management

10.1 Introduction and Terminology

10.1.1 Concept of Cultural Ecosystem Services (CES)

During the last decades, ecosystem services (ES) became a significant concept in environmental and social decision-making (de Groot et al., 2010; Plieninger et al., 2013). ES provides necessary and beneficial services for human well-being (Constanza et al., 1997; MEA, 2005). There are four types of classification, commonly considered as provisioning services, regulating services, supporting services, and cultural services (MEA, 2005; Cheng et al., 2019). Cultural ecosystem services (CES) are those nonmaterial benefits that are obtained from ecosystems through spiritual enrichment, recreation, aesthetic experiences, cognitive development and reflection (MEA, 2005), influence, quality of life, and human well-being. Although CES are understood as intangible and nonmaterial benefits, they are derived from the ecosystem. In this way, besides other ES, they are important in every society and community, and it is urgent to increase public awareness of CES to protect the environment from future degradation causes (Wallace, 2007; Abualhagag & Valánszki, 2020). In recent years, CES-related research has been carried out, which represents a wide range of approaches to defining, assessing, and mapping CES (Hernández-Morcillo et al., 2013). Because researchers, practitioners, and decision-makers from many disciplines are dealing with the CES concept, the meaning and interpretation of it differ according to the sociocultural background, geographic location, and professional background (Blicharska et al., 2017). In this way, several classifications exist, among which the most commonly used are the following categories developed by MEA (2005): spiritual and religious, recreation and ecotourism, aesthetic, inspirational, educational, sense of place, and cultural heritage.

10.1.2 Heritage as CES

According to the Cambridge Dictionary, the meaning of heritage is as follows: "features belonging to the culture of a particular society, such as traditions, languages, or buildings, that were created in the past and still have historical importance" (Cambridge Dictionary on-line, 2020). However, in the scientific literature, the definitions of heritage can be clustered into three main groups. The first approach is mainly based on the Millennium Ecosystem Assessment, which means the cultural heritage and its benefits derived from ecosystems and landscapes (MEA, 2005). According to this approach, cultural heritage can also be understood as traditionally important species, landscapes, and forms of land uses (Nahuelhual et al., 2014). The second interpretation is built on the regulation of cultural heritage, which mainly means the protection of remains of historically important buildings and archeological sites. The third approach is the broadest: cultural heritage is interpreted as connection with the past, which covers tangible and also intangible elements, such as objects, places, memories, and occasions (Hølleland et al., 2017). Parallel with these, others highlighted the part of the meaning that describes our relationships with the landscape. Harrison (2010) also emphasized that the term covers the different methods for protection as well as those processes, which can help decide whether something is important enough to remember. Both the material and intangible elements of cultural heritage can increase identity and, in this way, improve the communities (Tenberg et al., 2012). It can also mean that the heritage as CES contributes to the survival of the communities. The interpretation and perception of cultural heritage differ according to the sociocultural background of the individuals. Furthermore, heritage always changes, because society constantly reappraises it (Tenberg et al., 2012).

10.1.3 Meaning of Heritage in GI

What we consider "urban green infrastructure" has a parallel history linked to settlement development itself. "Londoners have been creating green infrastructure for two thousand years," as stated by Tom Turner in an article in which the current planning process and also heritage issues of London's green infrastructure were explained to the public (Turner, 2017). Not only London but also other historic towns and villages have their own but definitely diversified tradition of establishing, using, and managing urban greens. The varying traditional ways how communities are attached to green spaces could be determined by the geographical and national positions of the particular urban landscape which set the natural, social, economic, and cultural framework of UGI. Human activities such as planting or maintenance techniques (e.g., open lawn or shady parks? trimming or not trimming?) can ensure a unique character as well as a specific recreational activity, such as sports (cricket or petanque) or feasts. One of the most well-known traditional human activities connected to urban GI is the Hanami (flower viewing or Japanese Sakura Feast). As a long-term tradition, the cherry flower watching is an essential part of the GI heritage in Japan, with all of its activities and spaces defined. In landscape planning and design practice, green infrastructure heritage is more likely referred to specific urban green spaces. These are different physical green features in the urban spatial network characterized by specific structural attributes and heritage value. We propose that there are three structural types of urban green spaces, namely, areas, linear elements, and so-called green objects, classified by one's spatial characteristic. The most significant urban green areas recognized by international heritage institutions are historic urban public parks (e.g. Central Park, New York) and gardens (e.g., Royal Gardens in London, Orto Botanico di Padova, Italy, or Gethsemane Garden, Jerusalem, Israel) (Fig. 10.1), historic cemeteries (e.g., Cimetière du Père-Lachaise, Paris), and historic urban forests (e.g., Bois the Boulogne, Paris). Among urban linear elements, historic alleys such as the Unter den Linden in Berlin and riverside walks like the quay-side alleys in Paris could be mentioned. Particular elements within the urban GI network are the individual trees with a high heritage value (e.g., Tree of Hippocrates, Kos, Greece.)

Throughout the history of towns and cities, urban green areas have traditionally had functions relating to agriculture and horticulture as well as representation, well-being, or urban hygiene (Lichtenberger, 1998). A significant step in the evolution of urban green infrastructure was when community ownership and public use started to gain an overall importance. First privately owned gardens were partially opened to the public, and then public parks and gardens were planned and implemented meeting the actual needs of the urban community. Spontaneously grown urban vegetation has also started to gain heritage values as we could experience during the

Fig. 10.1 The thousand-year-old olive trees of Gethsemane Garden, Jerusalem, Israel, a historic garden acknowledged and known worldwide. (Edith Nagy, 2018)

Fig. 10.2 The High line park in NYC, USA. (Authors, 2019)

project formation of Landscape Park Duisburg-Nord, Germany (1994), or High Line Park, New York, USA (2009) (Fig. 10.2). Secondary grown and ecologically maintained urban habitats are being integrated more frequently into public urban green spaces, even in historic parks, and managed as a part of urban heritage, so-called urban nature as explained by Gobster (2007). We can conclude that heritage in GI is a complex issue that does not exclusively refer to historic nor to cultural phenomena but are well rooted in the past and, in the meantime, gives alternatives to the future. The heritage significance of green infrastructure continues to be recognised mainly by national and international heritage institutions, highlighting the active role of individuals or local communities.

10.1.4 Heritage Management in the Twenty-First Century (Different Approaches of Heritage)

Urban landscape has an ultimate characteristic – a constant change. Green infrastructure, as part of the urban landscape, is even more influenced by change because of its strong and fundamental relationship to living organisms and ecosystems. The present understanding of heritage in GI reflects a merged approach by identifying living or reviving traditions connected to urban greenscape as well as detecting specific urban green spaces with a heritage value. The heritage package of urban GI is an exciting mixture of human activities and particular places, structures and objects, old and new, artistic and ecologic, social and economic components. What to identify as a part of the package is an important question and provides ground for theoretical and methodological diversities.

Green heritage can be identified at the international, national, or local level. Athanasiadou (2019) highlights the special issues and all the current dilemmas about green heritage, noting how to "identify the worthy character and elements" and what to do afterwards. At an international level, UNESCO World Heritage is the highest heritage label available. The organization keeps count of historic gardens and parks and other urban GI features listed (e.g., alleys and planted promenades) as part of cultural landscapes that are also significant elements of the UGI network. Green heritage could be handled on a national or municipal level, classified as heritage of national or municipal interest, set by law acts, plans, and strategies. Identifying and managing cultural heritage are aided by guidelines and handbook issued by ICOMOS and IFLA based on the Venice Charter (1964), and more specifically related to historic gardens, in the Florence Charter (1981), which was the first to be considered a historic garden as "monument" and also set objectives, maintenance, restoration, and reconstruction rules as well as legal and administrative protection issues. Sales (2000) defines the significance of a historic garden by its "distinctiveness, importance, unique quality, comparison value and specific merit," which could be relevant for other historic green infrastructure elements, too. Since 1964, national and international networks have been set (e.g., European Garden Heritage Network), surveys were carried out (e.g., Historic American Landscape Survey), and databases and registers have been started to be developed. Supposingly one of the longest traditions in garden heritage management is practiced and documented by the 138-year-old English Heritage Trust. According to the actions listed above, more and more elements of the urban green heritage are now designated, registered, and documented, and articles of protection and management are developed worldwide. As green being a newborn in the family of monuments, as a living monument, there is still a lot to do.

Derived from the nature of green heritage [4] [NIR5], "its appearance reflects the perpetual balance between the cycle of the seasons, the growth and decay of nature and the desire of the artist and craftsman to keep it permanently unchanged" (Article 2, Florance Charter). A view further by Sonia Berjman (ICOMOS, 2001), "Town planners view public parks more as open and public areas within urban patterns, rather than inquire into their artistic or aesthetic significance or what their import is to the identity of the locality or the image of the city or town in question...gardens, parks and landscapes are virtually defenceless against rationalised administration and regular garden maintenance, against land-price politicking, against dynamically expanding towns and cities." Basically, there are two approaches, existing in parallel, to avoid the risks and preserve the values – restoration and conservation. Some declare historic gardens as a still moment in time that needs to be kept in order to be able to experience the past (Don, 2007). Such a common approach is included in the scientific method of restoration, which returns a whole site to a known earlier state. More convenient method of preserving urban green heritage and also creating green places for the present is conservation, in which a sensitive analysis of the importance of the current situation of the garden or park is carried out, before returning the landscape to a desirable earlier state (Sales, 2000). Conservation allows to keep and maintain several historic layers of the site at once, in its most preferable combination, for the protection of historic values, current and future use, and management.

There are several historic layers of urban green infrastructure heritage in order to ensure preservation. Heritage value can derive from the planning or design heritage of a specific person, such as Olmsted's landscape architectural heritage in North American cities, or can be a continuous work of varying activities of many stakeholders in urban greening. Urban green heritage can be identified in different scales that differ in methods and tools of protection.

10.2 GI as Heritage on Different Spatial Levels

10.2.1 Introduction, General Problems

Due to the scale of the particular study, we can approach and handle urban green heritage in a different manner. But, at all scales, the approach of work includes common steps – a historical survey as a base, an identification of the heritage values, and a proposal package of protecting the values detected. At a planning scale, we can infer the urban structure and morphological context of green heritage, while zooming in at a certain point to focus on the specific heritage issues of each element. At the urban planning scale, the historic green infrastructure network itself can embody the value and be dealt with as heritage, such as Baron Haussmann's emblematic green network in Paris or Frederick Law Olmsted's Emerald Necklace in Boston. In the case of a certain park, there are at least two scales to survey. It could carry heritage value due to its position in a historic network, although the park itself has limited importance deriving from its structure or park elements. Another level of identification is the park itself; its historic structure and elements could be considered as heritage value. To summarize, the network, the position in the network, and the element itself could carry heritage value each requiring different methods of planning and design.

10.3 GI as Heritage on Settlement/City Scale

10.3.1 Introduction, General Problems

To analyze the whole urban tissue, we highly depend on automatized surveying methods and tools, favoring GIS. Defining urban green infrastructure as a spatial network of vegetated patches, lines, and dots in the urban tissue can serve plenty of information about green cover, green density, and also the quality. From a social aspect, public green space supply, accessibility of public green spaces, and also the connectivity of the public green space network could extend the overall knowledge. Though spatial analysis could get us further to plan urban green infrastructure, it needs specific methods to reveal heritage. At such a scale, green heritage could be revealed by a GIS survey of historic town maps combined with historic spatial statistics and other historic data to be able to draw the important steps of change and evolution and also a reflection on the present conditions. Following from the nature of historic data, each survey could be a challenge to find relevant information on green space development. Each culture has a different approach to its green heritage, which could be dredged through their urban green strategies.

10.3.2 Best Practices/Case Studies

Starting our summary in Europe, first in Western and Central Europe [6], green systems in urban planning have a long history in Western cities, but the focus has over time diversified. In Berlin's current green infrastructure concept, there are three major orientations of development. The first objective was to develop a "Nice City" with a representative and recreational green network. Besides their recreational potential, the historic park frame of the German capital was pointed out as a fundamental source of identity; therefore their protection and development have a high priority. Another area of the strategy is the street network and their greenery. The renaissance of non-motorized urban mobility suppesed to lead to the better preservation and reconstruction of alleys. The conscious construction of the green space system of Vienna, the Austrian capital, began in the early twentieth century. In 1905, the demolished castle wall was replaced by a development-free green ring for the protection of nature and the health of the residents. In 1994–1995, the "Vienna Green Ring" and the "1,000 ha program" continued this work (Fig. 10.3).

Fig. 10.3 The development of the Vienna Ring as a chain of public green space and institutions in three steps: (1) Europe in the XIX century – Second military survey of the Habsburg Empire; (2) Europe in the XIX century – Third military survey of the Habsburg Empire

The Ring serves the basis for the recent green development (Mezősné Szilágyi & Báthoryné Nagy, 2017).

Budapest, the Hungarian capital, also previsions its urban green infrastructure development as a process preserving its public green space heritage. Its historic public park network, such as the City Manor Park (1785), City Park (1813) and People's Park (1860), Margaret Island (1908), and Buda Park Forests, provides the basic green patches of the city (Fig. 10.4). Then important historic green axes, including planted avenues and green corridors following urban creeks and the World Heritage Danube River bank area, are also listed. Some individual trees, like the oldest planted locust tree, a memento of one of the first planted avenues of the city from 1789, are also pointed out as part of the GI heritage. Besides drawing up an inventory, the city's development strategy sets static goals to preserve its heritage, more like a frame to be kept and restored, not like a living network to be managed and constantly developed (Great Assembly of Budapest, 2017).

Barcelona, the Catalan city in Spain, articulates its urban green heritages from a deep cultural and aesthetic perspective. In the city's green infrastructure plan, there are three elements defined as former private gardens with an artistic value, Montjuic's historic parks and historic urban trees. The green infrastructure of Barcelona was developed extensively in the 1980s, after General Franco's death. There are few sites of historic interest, which raises the value of urban green heritage. Twenty-seven percent of public urban green spaces are former private gardens with an artistic value due to their architecture, scenery, or plant use. All are listed as architectural heritage on a municipal level. Montjuic is the unique place in Barcelona where historic parks were developed in the nineteenth century. Sixteen of them are listed

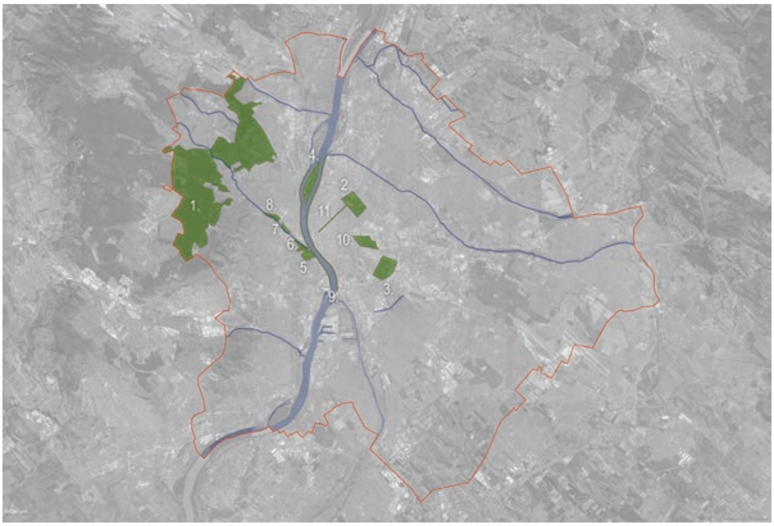

Fig. 10.4 Historic green network of Budapest, the capital of Hungary. (1) Buda Park Forests, (2) City Park, (3) People's Park, (4) Margaret Island, (5) Gellért Hill, (6) Tabán, (7) Vérmező Park, (8) City Manor Park, (9) Duna Corso, (10) Public Cemetery of Fiumei St. (Authors, 2020)

as heritage sites of local importance. The plan identifies specific urban plant use issues as part of the green heritage, such as the dominant use of the London plane, Date palm, or Southern magnolias in public places or historic private places, such as courtyards and cloisters. The strategy includes 138 heritage trees of all kinds, acknowledged on a municipal level, and outlines actions to protect its green heritage: 1) to identify what makes "green heritage", 2) to list and protect them, 3) to preserve historic sites, and 4) to preserve species marking the special identity of the city. The specialty of the Barcelona approach is to emphasize the character determining its historic green infrastructure and underlining it as a base of protection and further actions (Ajuntamnet de Barcelone, 2020).

If we move further north in the northern hemisphere of the globe, we can find cities where green heritage is more connected to natural issues. Protecting the diversity and habitats of forests and shorelines are the basis of Montreal's and also Stockholm's green strategies. It appears that cities with a history of living in harmony with nature place heritage at the center of their discussions of protection. Green strategies are focusing on the preservation of urban habitats and forests as well as environmental quality to ensure it.

In the southern hemisphere, Melbourne's urban forest management plan is only focusing on the management of the tree canopy heritage of the Australian city, as a thematic urban layer. As Melbourne is a planned city established in 1836, all historic alleys and planted promenades, parks, and gardens of the historic center have trees approximately of the same age. The dominating mass of large canopies and also the view of unique old public trees strongly define the townscape and also provide a liveable habitat. As the old trees' health conditions started to decline, urban forestry strategies were developed to preserve the canopy coverage on a long term, as an emblematic characteristic of the city (Melbourne Urban Forest Visual, 2020). Contrarily, in a short term, preservation of the ratio of canopy coverage means a mass, systematic, and planned step-by-step tree felling. In the case of Melbourne, the ratio of canopy coverage and also the spatial position of the trees are the target of protection, not the tree itself, to conserve the green character. In practice it means to register, protect, and replant the tree pits.

10.3.3 Methodological Issues, Lessons Learned

Considering the settlement scale, we can focus on patterns, density, and connectivity of urban green heritage as well as supply and accessibility in connection with the general urban spatial data. Based on these case studies, we can conclude that there are many cultural differences related to urban green heritage. The way we consider urban green as cultural heritage depends on cultural backgrounds. Cultural differences and traditions define the relationships and interpretations of public green spaces as heritage. One can argue that the northern countries usually place higher emphasis on the ecological aspects of urban green heritage, e.g., Montreal, Stockholm. On the other hand, southern countries where people live more on the streets, squares, and parks pay more attention to the cultural heritage value of UGI, e.g., Barcelona.

However, heritage patterns could remain unrevealed until a historic survey is conducted, mainly supported by GIS. Studying and drawing the historic green network in the framework of landscape and town history are essential in order to identify heritage. Each segment of the historic green network, such as a park, a garden, an alley, or a riverwalk, strengthens identity. Cities are committed to list and protect and also revive these places. Analyzing green networks on a city scale could help articulate the present role of a historic park or alley. Exploring past and present network elements, detecting historic periods, and drawing visible layers could help set dynamic objectives in order to protect, develop, and maintain urban green heritage. In this context, the conservation of a green heritage network does not automatically mean the restoration of an element of the network, if it has low heritage interest.

10.4 GI as Heritage at the Sub-Settlement Scale

10.4.1 Introduction, General Problems

In certain cities, we can find neighborhoods or districts with special historic green characteristics. In some historic quarters, by the orientation and network of streets, size of the lots, size and manner of the housing, size and shape of public places, private and public gardens, and the green spaces also have a heritage value as an "organic ingredient" of the historic character. These green spaces are mainly individually, sometimes even spontaneously, developed. More interesting in terms of green heritage are the quarters that were originally planned and designed with a significant green network, a balanced system of private and public green areas welcoming buildings, and other built infrastructure. Early examples could be Olmsted's Riverside District in Chicago, USA, or the residential areas built following the theory of Garden City of Ebenezer Howard, such as Letchworth, England. Workers' residential quarters of huge industrial plants were also developed in the same manner Europe-wide in the nineteenth and early twentieth centuries, where the workplace, home, institutions, public, and also private green spaces were planned to be in a reachable distance, within the border of the industrial quarter. A late successor of the model is the intensive and industrialized housing estate areas of the post WW2 era, dominantly in the Communist Block of Europe and the Soviet Union, where besides providing mass housing with blocks of flats, a large planned network of variable public urban green places were developed – a continuous system of public parks, recreational urban forests, planted roads, and public institutional gardens. These historic green districts are facing multiple-scale programming in terms of preserving green heritage. On the first level, the conservation of the layout, the green coverage, and also the balance between the built and unbuilt is measured. On the next levels, a detailed program of the conservation of parks, gardens, and alleys could stand. The most challenging issues of the conservancy are the changed expectations toward housing and green spaces in the twenty-first century and the headway of increased motorized mobility in public places.

10.4.2 Best Practices/Case Studies

In terms of public green networks, Olmsted created the most emblematic, ageless, and popular examples in the second half of the nineteenth century. Boston's Emerald Necklace is an example of how to develop a riverside public green corridor rooted in the surrounding neighborhoods (Fig. 10.5). The goal of the concept was to design a continuous linear park along the Muddy River by connecting Boston Common and Public Garden to Franklin Park. The work was started by controlling and "cleaning up" the muddy marshland along the river by driving the high flow into Charles River. After drying the shores, a green walkway was envisioned and built following the "gentle stream connecting numerous small ponds" to reach the downtown areas. The context of parks and natural habitats, waterways, and parkways create an illusion of nature in the city (The Emerald Necklace Conservancy, 2020). The core of the Necklace is still a chain of public parks, supplemented with sport and other outdoor leisure facilities, as well as nature reserves. There were two basic elements of Olmsted's concept – the park chain and its connection to the city, the parkways. Not only the core but also the tentacles reaching out the neighborhood were designed and developed at the same time. The park chain and its connecting parkways as a complex serve as a green heritage. The basic challenge of the historic park system is to keep up with the twenty-first century needs and also preserve the main characteristics of the past (Fig. 10.6). The most sensitive parts of the system are the parkways where a heavily altered urban landscape was developed due to motorized traffic. The conservation and management are run by an NGO called the Emerald Necklace Conservancy through projects and programs to restore and renew the landscape, waterways, and parkways of the Olmsted-designed park system. The NGO unifies many public and private park partners to prioritize, fund, and implement restoration initiatives throughout the park system. The manner of the site's conservation is articulated to keep the main goal, the vision of Olmsted, and also to keep the original main structure. But the process is flexible on the details and the methods of maintenance to reach sustainability (e.g., new style of plant use to be more sustainable). Civic partners and voluntary groups are essential in the development and place-keeping as well as awareness-raising to ensure long-lasting knowledge about the Emerald Necklace.

Another interesting example of a historic park system of Olmsted and his colleague Calvert Vaux was developed in New York City. The center of the system is Prospect Park in Brooklyn, which was originally planned to reach out to the neighborhoods with four radiating lines developed as parkways (Fig. 10.7). One out of the four, namely, the Ocean Parkway, was realized within the project as the first

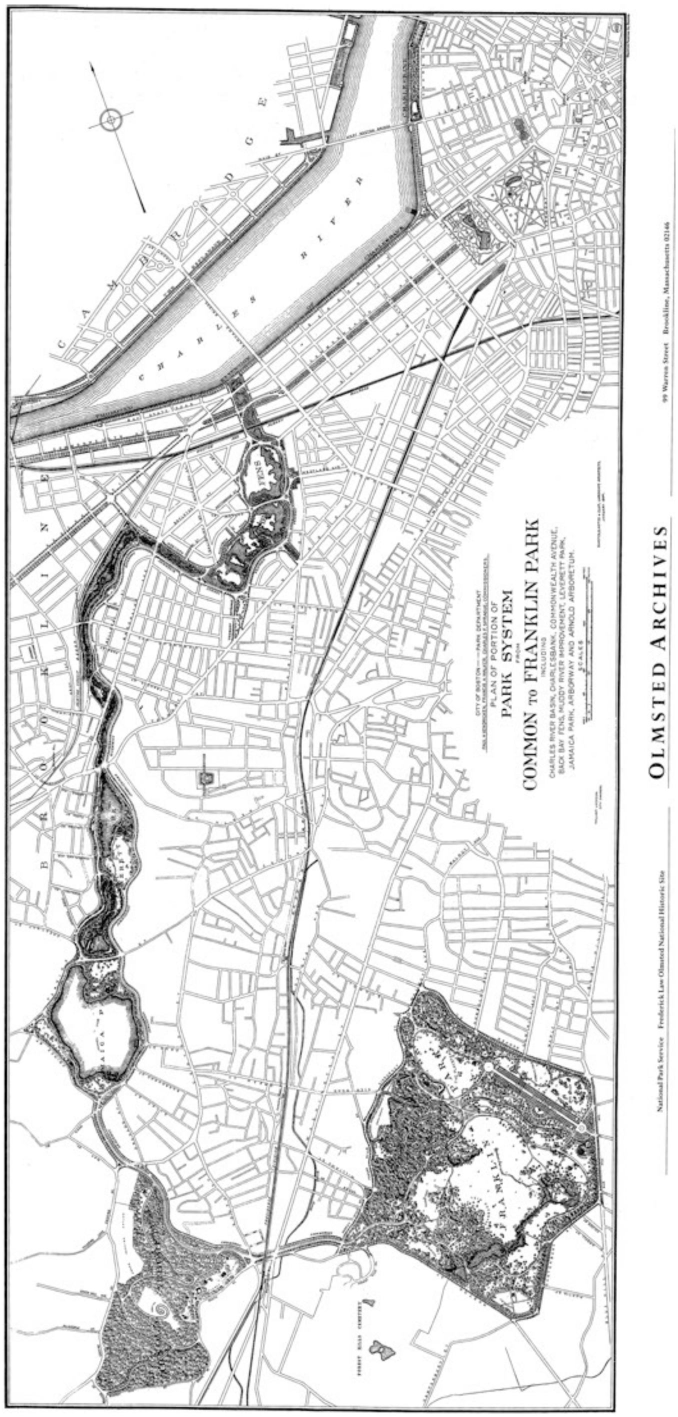

Fig. 10.5 The historic map of Olmsted's Emerald Necklace (https://www.emeraldnecklace.org/, 2020)

Fig. 10.6 The Boston Common, one of the oldest green open spaces along Olmsted's Emerald necklace, Boston, USA, (Authors, 2019)

Fig. 10.7 An original bridge in Prospect Park NYC, USA (Authors, 2019)

parkway ever built in the 1860s, which not only served as a physical connection between places but also provided beautification, joy, and recreation in travelling and walking. In Olmsted's dream, the parkway had several separated lanes for the different means of transport, divided by alleys and green stripes. It was modeled after the Avenue L'Impératrice in Paris or Unter der Linden in Berlin, but on a more grandiose scale. Carriages, pedestrians, horse riders, and also bicyclists all had separate lanes with green space. Still, although Ocean Parkway is an important green axis connecting Brooklyn with the beaches, it faced a radical change in the second half of the twentieth century due to car traffic. In the 1950s, Ocean Parkway's northernmost section was demolished and replaced with the Prospect Expressway. To prevent any further compromise and deviation of the historic design, in 1975 the city designated Ocean Parkway as a scenic landmark and then later listed in the National Register of Historic Places in 1983 (New York City Parks, 2020). Due to legal protection, major federally funded restoration and new non-commercial zoning restrictions were introduced to preserve the original goal and main characteristics of Olmsted's first parkway. Though the details have changed, we see no riding horses but driving and parked cars, the idea and the basic structure of the parkway still remains. The secret of the Ocean Parkway is the manner of public space sharing in a linear open space that was much ahead of its time and still a current trend in the twenty-first century's urbanism (Fig. 10.8).

The conservation of historic city parks is showing a similar character in approach to the case of restoration of Berlin's Tiergarten and New York's Central Park – conserving the general layout, style, and historic character but developing it in detail to fit modern standards, relevant codes, and current needs. Besides similarities there are also significant differences. The Tiergarten Berlin was originally a hunting forest of the emperor, developed along the floodplain forest of the Spree River. It was turned into a landscape park in the nineteenth century designed by the famous landscape architect Peter Joseph, Joseph Lenné, and later on a little adjusted by Albert Speer during the Nazi era. During and following WW2, the park trees were used for the short-term necessities of firewood; then the park was a vegetable garden. The restoration of the park started after the war and was completed in the 1950s with a massive plantation, even in the natural habitats and wilder areas (Grün Berlin

Fig. 10.8 The Ocean Parkway in the era of Olmsted and now. (www.nycgovparks.org; www.spinlister.com, 2020)

Gruppe web-site, 2020). The heritage value of the park is not the footprint of one particular historic area. "Its true heritage may lie in the consideration and representation of all times at once," stated by a conference paper on green heritage (Tiergarten, Landscape of Transgression – International Symposium, 2015). It is a green open space representing the breath of German history in one place; therefore it became a target of debate and remains challenging to heritage conservation specialists. Some are entitled to question classic preservation praxis that is limited by the reproduction of a specific time layer of the park, ignoring the complexity and also the progress of change, as a part of the heritage (Fig. 10.9).

Just as it is in the conservation process of Central Park, New York City, long-term goals are set to preserve the original vision of Olmsted and Vaux and the layout as well as the network of the man-made landscape elements (Fig. 10.10). The historic 340-ha park was created to provide a public green open space for recreation, as well as an experience of nature in a scenic way. Characteristic and enjoyable vistas were created, which was one of the bases of the concept. The Central Park Conservancy created in the 1980s is responsible for management and involve many public and private partners (Central Park Conservancy, 2020). The main conservation goal is to preserve the original design vision and layout but periodically renew the elements to fit current design standards and codes related to environmental sustainability, social care, public health and safety, and accessibility. It also needs to serve regular and occasional park users, thus requiring regular refurbishment to meet actual real-time needs. In that case heritage values were defined in two levels – on the level of the original concept (e.g., vistas, layout of walkways, ponds, elevation of viewpoints) and on the level of historic elements (e.g., sculptures, bridges,

Fig. 10.9 Tiergarten, Berlin, Germany (Authors, 2019)

Fig. 10.10 The vast green open space of temple in Berlin. Methodological issues, lessons learned. (Authors, 2019)

pavilions, old trees). The conservation of the concept is rather flexible on material use or techniques, while the historic elements are basically restored in their original way. Good examples of this process are the playground area or the walkways that could regularly get a new look meeting modern needs and techniques.

Regarding the subsettlement scale, we can admit that conservation methods are merging the methods and approaches of the settlement scale and also the object scale. We can still experience a double-scale approach in the process to define values and conservation goals and techniques. It is interesting to consider general layout, original vision, and goals as more significant particles of the heritage value than a certain construction or a plant. Therefore, the slogan of conservation could be "Conserving the concept of the designers but renewing the details" to meet twenty-first century standards, relevant codes, and needs (e.g., in Central Park or Ocean Parkway). It is a current debate among conservation specialists whether to choose a significant era and make a reproduction of that time or conserve and develop the historic green space as a multilayered living heritage, conserving its diversity. The first approach sets static goals and creates a version with less contact of the present. The second approach gives more challenges to conservation specialists but provides a long-term solution that involves the past and the present.

10.5 GI as Heritage on Object Scale

10.5.1 Introduction, General Problems

Arriving at the object scale, the most significant urban green heritage is the urban tree. Each culture has its own history of admiring old trees. Ancient cultures eulogize mature trees; they were treated as gods. Aged trees were personalized and are still actors of legends and could have religious significance. There are certain species that gain importance for a nation and a place in its mythology like Zeus' oak or olive trees in the Muslim world. The result is that legendary tree species were planted, admired, and protected until today. Trees could get attention as they are planted in an important place in history or also in connection with important historical persons. The cultural heritage value of a tree could come simply from its age – veteran trees predictably receive respect from the communities. The conservation of urban heritage trees is challenging. One must conserve and communicate the legend and also the individual tree itself. The old urban tree individuals suffer from the effects of twenty-first century urban environment – pollution, physical damage, drought, or heat. It needs sensible care to maintain and restore heritage trees.

10.5.2 Best Practices/Case Studies

Some nations and communities take special care to preserve their legendary trees. Among many others, Lebanon and Ireland serve as good examples. In Ireland an umbrella non-governmental organization covering all related bodies called the Tree Council of Ireland was established in the 1980s to help protect trees and develop a tree culture. With its shared information and consultation service, one can get detailed information about trees and how to plant, maintain, and protect them. The Council published a book on the heritage trees of Ireland to emphasize their importance. The book is like an expanded tree inventory in which all relevant data as well as a description of the trees' history and specific information of the history of the maintenance and also the connected legends could be read (Fennel, 2014). Conservation of heritage trees is supported by local, national, or international legal frameworks that help to supply the trees and also raise awareness and find partners such as in the case of the cedars of Lebanon. The veteran cedar trees, so-called the Cedars of God, which today hold World Heritage status, are not only the symbols of Lebanon but also a reference of sanctuary from the very early times till now, as was mentioned already in the Epic of Gilgamesh and also in the Holy Bible. Its timber was very valuable, which almost led to the vanishing of the cedar forests in Lebanon. The official protection and a worldwide importance of the trees as symbols could lead to legal protection and conservation of the remaining forests (Fig. 10.11).

The Tree of Hippocrates in Kos, Greece, is a protected veteran plane tree under which Hippocrates taught his pupil the art of medicine according to the legend. The

Fig. 10.11 An old cedar tree in the Ceddars' Groove, symbols of God, El Shouf, Lebanon. (Edith Nagy, 2019)

tree stands in the town center. It is surrounded by a small fence and retaining wall; its branches are supported by metal scaffolding. The tree itself is about 500 years old, but it could be the descendant of the original plane tree that was standing on the same spot 2400 years ago. Seeds and cuttings of the tree and also the myth of the Hippocrates Plane were widespread all over the world. Therefore, we can find many current Hippocrates Planes planted in North and South America, Europe, and also in Asia planted in medical university campuses, library gardens, and colleges.

A progressive approach of urban tree heritage conservation, even receiving an award from ASLA, was introduced in the project material of Moore Square development plan in Raleigh, USA, projected by Christopher Counts Studio, Brooklyn NY (ASLA web-site, 2013 ASLA Professional Awards, 2020). Moore Square is one of the remaining planted squares dating back to the origin of the town, serving an example of early American urbanism and also an important historic place in town. The original character of the square consists of a shady area, crossings to reach the neighboring roads, and a sunny field in the middle. The very strong vision of the project was to conserve the shady and historic character of the 200-year-old square for the next 100 years, which meant to work out a dynamic concept of tree management in the long term. All other design elements were following the guidelines of the tree conservation program, drawing the basic layout of the square as well as the techniques that could be used for construction. Such an approach could preserve the tree heritage of a historic square for long, even if some individual trees must be cut, and others must be replanted in a certain time. It is ironic that in the meantime, another project was realised, the results of which are still visible today.

10.5.3 Methodological Issues, Lessons Learned

Though tree legends are still alive in several cultures, heritage tree conservation is acknowledged in different ways. Inventories and cadastres could help register the changes, besides listing measures and conditions, even the history and cultural cohesion of a certain tree, in order to plan conservation goals and actions. Pictured monographs published and spread could raise awareness and appreciation of heritage trees, their legends, and cultural importance, such as in Ireland or Lebanon. An inventory and also a conservation program run on a national or even international level could be effective all in protection, communication, and awareness-raising, such as in Lebanon. An important issue is that the legend of trees could be conserved even if the particular tree must be cut or replaced. A current practice in heritage tree conservation is to replant the cut tree by an individual grown from the seeds or the cuts of the original plant. A legendary tree and its myth could even be transmitted worldwide, such as the Hippocrates Plane. An urban tree stand could serve a cultural heritage as a plant community, as a constantly developing urban feature just like in Moore Square, Raleigh. Sounds weird or not, in this case, current heritage trees could be cut to serve the long-term vitality of the heritage tree community as a group.

10.6 Application and Implementation: The Role of Public Participation

10.6.1 Introduction

Researchers and decision-makers increasingly highlight the need for (public) participation during planning and strategy-building (Chen et al., 2019). Many international agreements, e.g., Aarhus Convention (UNECE, 1998) or the European Landscape Convention (Council of Europe, 2000), emphasize the importance of locals' participation in decision-making. Furthermore, the Millennium Ecosystem Assessment expressed the lack of recognition of CES (e.g., heritage) in landscape and urban planning. In close connection with this, it also states the importance of the improvement of citizens to participate in the planning and management processes (MEA, 2005; Tenberg et al. 2012). Despite this growing attention on heritage as a CES, its assessment is still challenging (Brown et al., 2015). The main reason for this is the special nature of CES, because their perception varies geographically (Sanna & Eja, 2017; Cheng et al., 2019) and depends on sociocultural background (Daniel et al., 2012; Paracchini et al., 2014). Further, the perception of heritage differs according to the individuals' backgrounds (Plieninger et al., 2013). Consequently, public participation is important during all stages of urban planning and management, from data collection to decision-making and implication. This is especially true in the cases of CES (and in this way in the case of heritage) evaluation. Traditionally the data gathering is mainly carried out by surveys (e.g., questionnaire surveys), frequently with participatory mapping (Paracchini et al., 2014; Brown & Fagerholm, 2015). However, recently significant technological advances (e.g., crowdsourcing geo-information) have also influenced the added value of the public participatory information, and they have redefined the role of these types of information (Plieninger et al., 2013, Bubalo et al., 2019).

10.6.2 Best Practices/Case Studies

Not uniquely the old times grew emblematic professionals, Copenhagen has recently exposed two outstanding urbanists, Jan Gehl and Tina Saaby, who gained international fame with their unique approach of urbanism and public participation. Jan Gehl, architect and urbanist, was the leader of the movement started in the 1960s, which wanted to reintroduce basic human needs for interaction, inclusion, and intimacy that seemed to be forgotten in the urbanization of the post World War II west. One of his tools is detailed and well-positioned surveying of local communities to be able to understand urban life. As we can read in his famous books, *Life between buildings* (1971) and later on *City for People* (2010), he created a new style of urbanism in which public strategies and policies were more developed around people's welfare and quality of life, to be integrated into local government policies (Gehl Institute, 2020).

Following the same core line, former chief town architect Tina Saaby is one of today's most progressive urbanists. She based her town development strategy on partnership with everybody who comes in and asks for it. Her partnership program called "Say 'Yes' Order" was started in the year 2010, in which city governance opened the door to each bottom-up initiative, no matter how crazy it seemed to be. It resulted in many innovative public space uses, unique and creative solutions, more committed citizens, and more effective maintenance. The goal was to involve a vast part of the community in preserving the common heritage, developing common public places, and helping everyday management (Saaby, 2015). Due to the program, public spaces, parks, and shorelines were renewed and rehabilitated, bicycle routes were developed, health and crime statistics progressed, and the city is now listed among the most liveable cities in the world.

Getting deeply involved in Melbourne's green heritage issues, one can join and experience a high level of participatory actions channeled into town development and management through the website *Melbourne for All People: Participate Melbourne*. All community projects are listed, project documents are transparent and available, a timeline of the project management is shown, contact participatory actions are advertised, and possibilities to send comments are opened. Green heritage issues such as the master planning of the Carlton Gardens World Heritage Site are also in a participatory process. A key element is to communicate well and easily the details of projects to raise awareness and enhance strong attachment. As a perfect example, 'Urban Forest Visual' project (City of Melbourne, 2020) creates an

Internet profile and an email address of each heritage public tree therefore the community can directly get contact with a certain tree, share ideas and information. It can also help the community mourning the loss of heritage, e.g., writing an email for the tree to be cut. Working out and communicating different timings for the interventions are also handy to be able to ensure better understanding and the possibility to get involved.

While online participatory tools were developed to help raise awareness and attachment of the community, most of the tools are also developed as an interactive online GIS database. Online registration of public urban trees is one of the most common participatory tools by which tree managers, decision-makers, and regular citizens and tourists can get and give up to date information on a certain tree. Like the websites and the mobile apps of New York City's Street Tree Map, Melbourne's Urban Forest Visual or Budapest's Tree Cadastre are all online GIS databases, indicating the exact geographical position of a tree, its actual condition, its recent value, and also its ES. These tools are generating a rising interest in public trees and help generate actual data of conditions. Participatory data input can support the maintenance team to detect casualties in time and prioritize the work without extra sources spent on monitoring. Both achievements could facilitate the preservation of urban green heritage.

In recent decades, from the several available participatory methods, the Public Participation GIS (PPGIS) was increasingly frequently applied (Brown & Fagerholm, 2015) that merges spatially explicit biophysical and perception-based data (Garcia-Martin et al., 2017). Public participation mapping is mostly referred to as three slightly different terms: public participation (PPGIS), participatory GIS (PGIS), and volunteered geographic information (VGI) (Brown et al., 2018). Among these, the first one is the most frequently used. PPGIS were used in several research fields, such as environmental planning, natural resources management (Dunn, 2007), planning and management of protected areas (Clement and Cheng, 2010), and management of urban parks (Brown, 2008). The widespread application of PPGIS is because this method makes possible the integration of a wide range of spatial data and can support the expert-driven mapping (Brown & Fagerholm, 2015; Scholte et al., 2018). In cases of urban green infrastructure planning and management, the following attributes can be involved in the mapping process: heritage values, special places, development preferences, perception of environmental impacts, quality of (historical) urban parks and open spaces, recreational resources, and state of the cultural ecosystem services (Fig. 10.12).

Several tools exist, which help implement the PPGIS method into practice. From these, the Maptionnaire is a frequently used one, especially in Europe and North America. It is a map-based online survey tool that makes the public participatory process simpler and more efficient. The online editor is flexible during the elaboration and publishing process of the survey. It helps the planners and decision-makers in collecting, analyzing, and visualizing spatial data. At the same time, maptionnaire enables local citizens to exprgage residents, interpret results, and make planning smarter (Maptionnaire web-site (2020)).

Fig. 10.12 General steps of the PPGIS method – examples from Hungarian study areas. (Authors, 2018)

The tool was applied in Helsinki during the National Urban Park project, which intended to combine the remarkable cultural and ecological values of the city. Maptionnaire helped in survey design and the online public engagement process. More than 1000 responses were received about the opinion of local citizens related to the National Urban Park of Helsinki, and place-based results were visualized on "heatmaps." The survey findings served important information about this possible UGI element both from ecological and cultural (heritage) points of view. Among several applications of the online map-based tool in Germany, the case of Düsseldorf is especially interesting. The so-called Blaugrüner Ring (Blue-Green Ring) of the city is a network of many of the center's green spaces, parks, and the Rhein riverside. Several important cultural sites of Düsseldorf (e.g., museums, galleries) are located along this ring. The city proposed to merge together the cultural elements with the UGI utilizing the potential of the ring. During this process the perception and experience of the locals are essential. In order to gain this information, Düsseldorf also used the online map-based survey. The results could help enhance a complex heritage-environment experience of the citizens by this UGI element. During the surveys the online mapping tool can be combined with social media platforms (e.g., Instagram, Pinterest). In many cases, this combination of tools has been used for collecting local residents' memories and assessing culturally significant (green) places (e.g., in Sipoo, Finland) (maptionnaire). Several variations and adaptations of the map-based participatory surveys exist and increasingly frequently have been used; however, all of them were mainly based on the PPGIS theory and logic.

10.6.3 Integration of Principles and Methods into the Planning and Management Practice

The evolution of UGI is constant – besides its succession process, it changes together with the urban society and city structure. It must be considered as a process that has several stages, one of which is the moment we experience now. Therefore, a deeper involvement of the community in urban planning and design, also in the management of public urban greens, is essential as we experience and generate changes. The participation techniques are currently developing worldwide. Still, urban green infrastructure is a living heritage; it needs special understanding of the change and also the origin of change. All developed participatory methods are very useful to attach the communities to the process and strongly keep them involved. Detecting and monitoring the heritage, collecting and telling common memories, and channeling all of the previous into urban planning and design are now becoming general practices. Map-based online interactive methods available also on smart tools supplemented with real-time contact actions and fundraising are the particles of a successful toolkit. After the conservation project is realized, a key issue is to provide continuous and professional maintenance, which is a source-demanding activity. Sources can be multiplied if each stakeholder takes its part to keep heritage value in a good condition. Not to forget, the process still requires professionals to organize, evaluate, and control and also to prepare actions, in which case a successful model of place-keeping could be carried out to preserve green heritage for a long term.

10.7 Conclusions

Urban green heritage as CES provides several benefits for human well-being. CES are important for local communities and for whole societies. In order to protect heritage, it is essential to raise public awareness of it. The several existing heritage-related works from different fields present many assessing and mapping possibilities. However, it also causes plenty of different meanings and interpretations of the term and related issues. The interpretation of cultural heritage differs according to professional and sociocultural backgrounds, as well as geographic location. Despite these, researchers, practitioners, and decision-makers agree that heritage can increase the identity and improve communities.

Due to the nature of heritage, the heritage in GI could be identified as a complex issue rooted in the past. Deriving its spatial character, it could be a park or garden, or long and linear elements such as an alley, a promenade, or a riverside walk or a certain object in the urban tissue, such as an old tree. If green infrastructure is considered as being dynamic heritage, it faces constant change, which makes it more vulnerable. To be able to preserve heritage GI in the long term, it must be identified, listed, integrated into the twenty-first century urban green infrastructure network, and communicated to the public. In order to meet these expectations, dynamic goals should be set, which could include the change. Among many other forms of conservation, it is the most suitable method to preserve green heritage owing to its complexity in time and space. According to international practice, among many similarities, urban green heritage conservation shows particularities in different spatial scales. At the city scale, the planners can focus on patterns, density, connectivity, supply, and accessibility issues. Analyzing green networks on a city scale could help articulate the present role of a historic park or an alley. Exploring past and present network elements, detecting historic periods, and drawing visible layers could support the best conservation. The most interesting uniqueness of the scale is that the conservation of a green heritage network does not automatically mean the restoration of an element of the network. In subsettlement master plans, a double-scale approach could be outlined in which the general layout and original visions are more significant goals of heritage protection than a certain construction or a plant. Arriving at the scale of urban trees, besides the conservation of veteran trees an important issue is the legend of trees to survive. One progressive approach of heritage tree conservation is when the tree itself is cut to serve the long-term vitality of the heritage tree community as a group, or to preserve the historic place of the tree in the urban tissue, with another individual. No matter the scale, identification, registration and conservation of the GI heritage stays in common.

Several researchers, practitioners, and also international documents, e.g., Aarhus Convention (1998) or the European Landscape Convention (2000), emphasize the importance of public participation in landscape and urban planning. This is essential in the cases of data collection, evaluation, decision-making, and implementation processes related to urban green heritage, thanks to the place dependence and sociocultural dependence of it. Many tools and methods exist for this from the traditional, paper-based surveys and interviews to the new, modern online applications. Among the available participatory methods, we highlighted the Public Participation GIS (PPGIS), which is suitable for urban green heritage management. PPGIS combines perception-based and spatially explicit biophysical data. From the existing tools, implementing this method into practice, the maptionnaire is commonly used in North America and Europe. This online map-based survey tool has been used in several urban green heritage projects during the last years, e.g., National Urban Park project in Helsinki, Finland; complex heritage-environment experience development based on the “Blaugrüner Ring” in Düsseldorf, Germany, collecting residents’ memories and evaluation of culturally important green places in Sipoo, Finland.

After all these case studies, one can see that urban heritage issues, including green heritage, independently from scale and manner, must be viewed as complex. The identification of heritage plays a key role that needs variable historical data. In many cases, heritage GI changed over time and stays as an imprint of different eras. The careful reading of the imprints and the detection of historic layers have outstanding importance in understanding the relevance of the heritage and also to be able to project the future. A coherent analysis of “The Historic Context” and “The Heritage Itself” seems to be essential to be able to identify and manage the heritage values in the most sensitive way.

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Chapter 11
Transdisciplinary Co-design and Implementation of an Urban Ecological Green Infrastructure Landscape Performance Monitoring Plan

Christopher A. Sanchez, Chingwen Cheng, Daniel L. Childers, and Abigail York

Abstract Cities are increasingly using nature-based approaches to address urban sustainability challenges. These approaches leverage ecological processes associated with Urban Ecological Infrastructure (UEI) to resolve issues through ecosystem services. The growing use of UEI to address urban sustainability challenges provides opportunities to bring urban researchers and practitioners together to co-produce UEI design, monitoring, and maintenance. Until recently these co-production processes have received little attention in the literature. We used a social-ecological research approach to examine a co-produced UEI design process and the outcomes of the associated UEI project—bioretention basins on the campus of Arizona State University (Tempe, AZ, USA). We collaborated with key project researchers and practitioners to produce an ecohydrological monitoring protocol for the site to measure water quality, hydrology, soil moisture, and plant transpiration. We then implemented this protocol to monitor and evaluate UEI performance outcomes. Finally, we conducted semistructured interviews to document the transdisciplinary co-production design process and outcomes. The co-production experience resulted in observable change in attitudes among participants toward the integration

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of urban ecological research with the monitoring of UEI performance. Our results confirmed that the UEI bioswale system met the stormwater design goals of retaining 2 h 100 year storm events onsite, with some additional capacity for nutrient reduction. These data and results are being used by practitioners to gain SITES certification for the project and to inform future design and management of UEI across the ASU campuses. Our work also provides insights into the transdisciplinary processes of UEI design and evaluation.

Keywords Nature-based solutions · Landscape Performance · Co-design process · Sustainable campus design and monitoring · Urban ecological infrastructure

11.1 Introduction

As cities grow older and larger in both population and spatial extent over the past century, so has the strain they put on resources and infrastructure (Grimm et al., 2008; Grove, 2009; Childers et al., 2015). As climate change has aggravated the intensity and frequency of extreme events, many cities are facing the pressures to redesign their outdated stormwater infrastructures that were designed based on past storm intensity and climate trends and have now exceeded their capacity (Rosenzweig et al., 2018; Cheng et al., 2017). Water resources and related infrastructure in arid land southwestern US cities face growing challenges related to extreme events, decreasing water supply, and increasing demand (Larson et al., 2013). Cities have been relying on built, gray infrastructures, largely consisting of engineered and man-made components to address these challenges in order to provide the essential services for sustaining critical social and biophysical systems in cities (Neuman & Smith, 2010). However, gray infrastructure approaches are increasingly met with issues associated with adaptive rigidity (Gilrein et al., 2019; Helmrich & Chester, 2020) and systemic failure (Chester & Allenby, 2019) in the face of increasing uncertainty in both climate and population trends in cities.

In an effort to adapt to this future uncertainty, many cities are increasingly using design-with-nature solutions and engaging the design-ecology nexus (Childers et al., 2015). These approaches leverage ecosystem functions associated with existing or newly constructed ecological structures to provide services, or benefits, to people (Grimm et al., 2016). Moreover, the ecological resilience concept has provided new insights into infrastructure design to enhance adaptive capacity for resilient and sustainable landscapes (Ahern, 2011, 2013). Many different terms exist to classify these ecosystem service-based infrastructures, including green, nature-based, hybrid, and others (Hansen & Pauleit, 2014; Anderson et al., 2014; Grimm et al., 2016). At the same time, the landscape architecture profession has promoted the Sustainable Sites Initiative (SITES)—a rating system for sustainable landscape design—to encourage design strategies that help conserve, enhance, and restore ecosystem functions and minimize land development impacts.

Green infrastructure is a term used exclusively in a US context by the US Environmental Protection Agency and American Society of Civil Engineering, as alternative stormwater management practices for improving water quality and reducing stormwater runoff. In order to be as inclusive as possible of all forms of nature in cities, we will use the broadly inclusive concept of Urban Ecological Infrastructure (UEI; Childers et al., 2019). It aligns with the green infrastructure definition of the landscape architecture profession and includes all components of a city that support ecological structure and function and thus provide ecosystem services (Fig. 11.1). Notably, many forms of UEI have novel ecological structures and functions relative to their non-urban counterparts (McDonnell & Pickett, 1990), and many forms of UEI are hybrids of ecological and built components (Grimm et al., 2016; Childers et al., 2019). Important characteristics of UEI include (1) some level of human management of ecological structure and function to achieve desired ecosystem services, (2) ubiquity in the urban landscape, (3) provision of a variety of services and possibly disservices (Larsen, 2015; Grimm et al., 2016; Larson et al., 2019), and (4) a high potential for building urban resilience and adaptive capacity relative to gray infrastructure (Ahern, 2011, 2013; Cheng et al., 2017).

UEI is also increasingly a focus of study in transdisciplinary, problem-oriented urban research agendas (Felson & Pickett, 2005; Pickett et al., 2016). In the context of growing calls for transdisciplinary or convergent research (NSF 2018), UEI is an understudied space of convergence for urban ecologists, designers, and practitioners. Persistent calls have been made in the urban ecology literature for collaboration and research at the ecology-design nexus (e.g., Childers et al., 2015; Grove et al., 2016) and for a better understanding of how different actors conceptualize, navigate, and contribute to the design process and to the co-production of knowledge (Lawton & Jones, 1995; Felson et al., 2013; Steiner et al., 2013; Grose, 2014). The research we present here focused on transdisciplinary collaborations associated with the design and management of a stormwater UEI project—bioretention basins on the Tempe campus of Arizona State University. Our social-ecological approach explored the design process that produced an ecohydrological monitoring protocol that was then used to assess post-construction landscape performance of the site (Fig. 11.1). More specifically, we used this ecohydrological monitoring protocol to quantify water quality, hydrology, soil moisture, and plant transpiration in the bioretention basins. We used the results to evaluate UEI performance outcomes relative to the SITES program requirements. Finally, we used semistructured interviews to document the transdisciplinary co-production design process and outcomes, articulating the motivations and challenges to these kinds of transdisciplinary collaborations (Fig. 11.1).

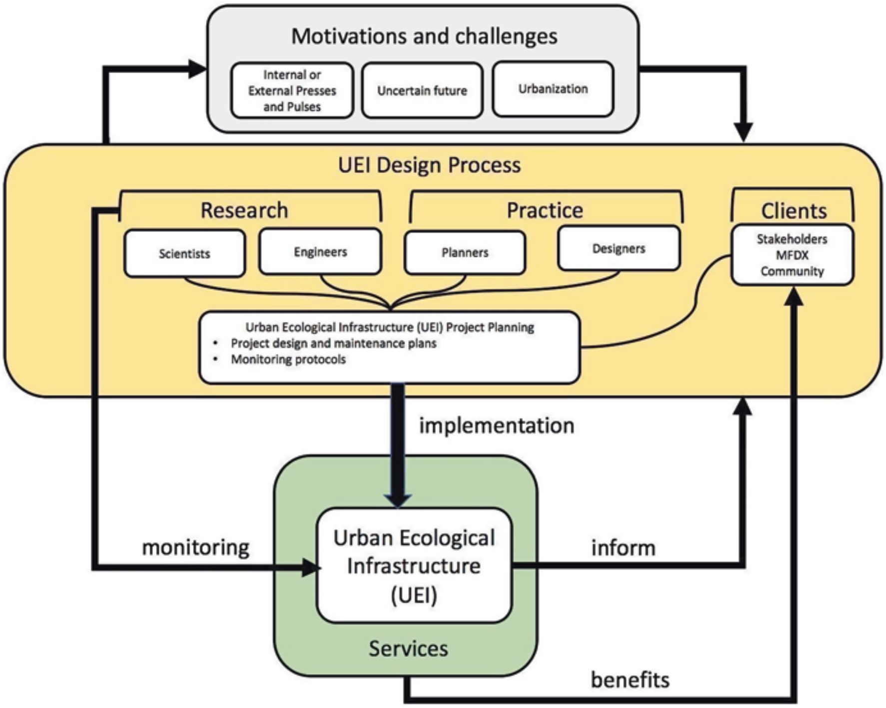

Fig. 11.1 Conceptual framework illustrating the co-production processes associated with the UEI design, maintenance, and monitoring. Our research documented the co-production process associated with the development of the monitoring protocol, application of the protocol (monitor), and use of the ecohydrological and biogeochemical data about project performance (inform). (Authors, 2019)

11.2 Methods

11.2.1 Site Description

The Arizona State University (ASU) Tempe Campus is located in Tempe, Arizona, USA, which is part of the rapidly expanding greater Phoenix Metropolitan Area. The ASU Tempe Campus has approximately 55,000 enrolled students and more than 10,000 faculty, staff, and administrators. The size and scale of the campus provide broad comparability to many urban and municipal areas. In 2016, ASU began an effort to redevelop Orange Street, a high-traffic thoroughfare in the center of campus. Before the redesign, Orange Street was a paved road, with foot traffic restricted to sidewalks. The Office of the University Architect identified Orange Mall as a high-priority intervention point to begin implementing sustainable UEI features into the campus due to its central location and large volume of foot traffic. In addition, the Orange Mall area, a 2-acre site, is a key drainage point for an 18-acre storm watershed extending north across the campus. This hydrologic convergence resulted in persistent flooding issues on Orange Street.

The Orange Mall redevelopment project transformed Orange Street into a shaded pedestrian mall (Fig. 11.2). Construction of the bioswale and bioretention basin UEI was completed in October 2017. The design goals of this UEI project included (1) social activation of the space using a variety of pedestrian-friendly structures such as benches, tables, lighting, and power outlets; (2) enhanced ecohydrological function with vegetated bioretention basins and bioswales designed to hold all runoff from 2 h 100 year storm events onsite; (3) co-benefits of capturing stormwater for passive irrigation; and (4) further benefits of microclimate regulation by vegetative transpiration.

Part of the Orange Mall redevelopment project was to rebuild the Student Pavilion building that subsequently received LEED Platinum certification for its sustainable building design. An overarching goal for the UEI project was then to achieve Sustainable SITES certification. The process of applying for SITES certification stimulated the collaborative development and implementation of an ecohydrological monitoring protocol to evaluate post-construction landscape performance. The SITES application must include the monitoring protocol, the methods used to develop and implement it, 3 years of monitoring data, and examples of how results were used to correct and improve the UEI design (Lady Bird Johnson WildFlower Center, 2014). This pursuit of SITES had key implications for decision-making in the design process that we will discuss later.

The redeveloped ASU Orange Mall includes walkways made of concrete and pavers interspersed with standalone vegetation and 525 m^2 of planted bioretention basins. The site contains a total of seven basins, which are divided into two primary

Fig. 11.2 Aerial imagery from Google Maps showing the ASU Orange Street (center, left) before and Orange Mall (center, right) after construction of the UEI project. (Google Map)

(east and west) drainage systems (Fig. 11.3). The west drainage includes three smaller basins (WB1–WB3), which are 90, 40, and 15 m^2 in size, respectively (total = 145 m^2) and the east drainage includes four larger basins (EB1–EB4) that are 165, 110, 20, and 85 m^2 in size, respectively (total = 380 m^2; Fig. 11.3). These basins are connected with a series of shallow runnels, and flow from the east and west drainages converges at a south-central overflow basin, where any stormwater overflows are piped south to an off-site buried cistern. A variety of desert-adapted native vegetation species (n = 11) were planted across all of the Orange Mall basins. Roughly 80% of the plant community is comprised of individuals from five species: Fan West Ash (*Fraxinus* 'Fan-West' hybrid), Tall Slipper Plant (*Pedilanthus bracteatus*), Desert Spoon (*Dasylirion wheeleri*), Mexican Petunia (*Ruellia brittoniana*), and Compact Jojoba (*Simmondsia chinensis* 'vista').

Surface inflows to the basins were varied and dispersed. The EB1 and EB2 basins both received point-source inputs at their eastern terminus from curb cuts that drained surface flow from the remainder of Orange Street, while WB1 received significant inputs from the roof drainage from nearby buildings and roads to the north. However, the basins also received surface runoff from the impervious surfaces that surrounded them, making an accurate estimate of total inflow volumes impossible.

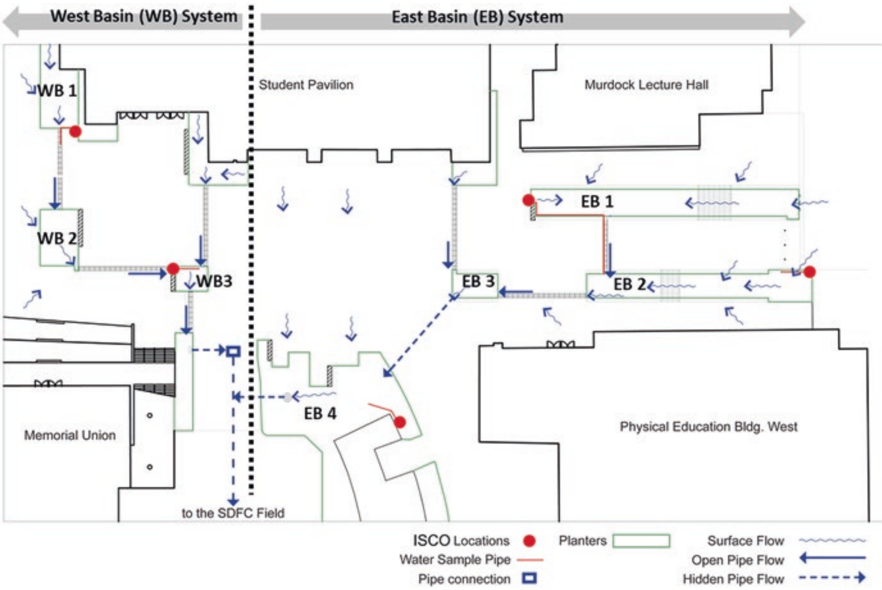

Fig. 11.3 Site design showing the east basin (EB) and west basin (WB) drainage systems and a total of seven bioretention basins (EB 1 to 4, WB 1 to 3). Water moving through the system generally flows south (down) and discharges to the athletic field on campus. The experimental design for the ecohydrological monitoring includes locations of the ISCO autosamplers and sampling lines and water flux sampling (water-level sensors and V-notched weirs). (Authors, 2020)

11.2.2 Co-production of the Monitoring Design

The actors that we studied fit into one of two categories: urban researchers or urban practitioners. We defined urban researchers as academic or research-based actors who work in the fields of urban ecology or urban design (e.g., faculty and students of ASU). We defined urban practitioners as non-academic actors, such as ASU designers, landscape architects, facilities managers, and external consultants, who were involved in decision-making for UEI projects. Our focus was on key design decisions and the relevant decision-makers; thus, we excluded other potential stakeholder groups (e.g., subcontractors, private organizations, or community members and students). Our goal was to document how the system was designed and how the monitoring protocol was developed, with particular focus on the development of the UEI monitoring effort and feedback phases (Fig. 11.1).

We used two qualitative data collection methods to study the design of the monitoring protocol. First, when the monitoring protocol and research design were being co-produced in Spring 2018, we conducted participant observation of the dynamics between researchers and practitioners. During these meetings, researchers and practitioners worked together to co-produce a monitoring protocol that would be used to evaluate the performance of UEI at Orange Mall and to generate data to fulfill SITES reporting mandates. Participant observation of these meetings included tracking of various developments, participant dynamics and attitudes, and decision-making processes taking place in these meetings. Importantly, because we were active participants in this process, we used an ethnographic orientation with self-reflection on the experience of co-producing research with design practitioners.

Second, we conducted semistructured, in-depth interviews of 40–50 min in length with key researchers and practitioners: ASU researchers, landscape architects and facilities management personnel, and external consultants, landscape architects, and engineers. The interview instrument focused on understanding past experiences with UEI, the Orange Mall project narrative, unpacking of the project and monitoring of design process, and feedback on the motives, challenges, and opportunities associated with UEI design and monitoring. We recorded and transcribed interview audio after obtaining consent. For all interviews, detailed notes were also taken on participant attitude and body language. For one interview where recording consent was denied, notes were the sole source of interview data. Finally, we conducted these interviews with key project participants until saturation was reached and no new significant information emerged.

We utilized an open-coding framework for our initial review and content analysis of these interviews where we identified emergent themes and developed an initial codebook (sensu Elo & Kyngas, 2008). A second coding review utilizing a provisional approach was used to identify specific co-production knowledge gaps to refine the codebook and content analysis. Finally, we used an intercoder reliability check utilizing a 10% coding sample to verify the validity of the codebook prior to final analysis. All content analysis was conducted using NVivo 12 Mac (Version 12.3.0, https://www.qsrinternational.com/nvivo/home).

Fig. 11.4 Photos of bioswales and sampling equipment at Orange Mall. From left to right: (1) a flooded bioswale after a rain event in October 2018; (2) an ISCO 6712 sampler deployed on-site and disguised in a protective enclosure to prevent vandalism; and (3) the LI-COR 6400XT Infrared Gas Analyzer being used to measure transpiration. (Authors, 2020)

11.2.3 Quantifying UEI Performance Outcomes

Throughout Spring 2018, researchers and practitioners worked together in workshop-style meetings to discuss and develop a monitoring protocol to assess site performance and design outcomes. The protocol included ecological, hydrological, and biogeochemical metrics that met the research goals, as well as data needs for SITES reporting and practitioner interests (Fig. 11.4; Table 11.1). Unless otherwise noted, all analyses were conducted using R (version 3.3.3., http://cran.r-project.org/).

11.2.4 Water Quality

The designers and managers of the Orange Mall system were interested in achieving stormwater quality improvement for storms that exceeded the retention capacity of the basins. To measure outflow water quality, we used five ISCO® 6712 automated pump samplers to collect up to nine discrete stormwater samples per storm event between August 2018 and March 2019. We installed ISCO samplers at the inflow and outflow of the west basin system and at the inflow, mid-point, and outflow of the east basin system of the site (Fig. 11.1). Sampling lines were installed in curb cuts or runnels so that only water flowing between basins would be sampled. We used ISCO® 720 bubbler modules to automatically trigger sample collection at a water stage of 3.1 cm or greater—the minimum depth required to fully inundate the intake strainer. The samplers were programmed to sample at nonuniform fixed time intervals, with sampling occurring more frequently at the beginning of storms when the water quality was expected to change most rapidly (i.e., the first-flush effect; Lee et al., 2002; Hale et al., 2014). These fixed-time sampling intervals were set to 0, 5, 10, 15, 30, 45, 60, 90, and 120 min following sampler activation.

Table 11.1 Parameters included in the co-produced Orange Mall eco-hydrological monitoring protocol, including the type of data and associated metrics and the methods and equipment used in the field sampling

Data type	Metric	Equipment	Method
Hydrology	Water quality	ISCO 6700/6712 auto-sampler + ISCO 720 bubbler module	Sample collection triggered by water level
	Water quantity	V-notch weir + ONSET water level autologger	Autologging probe
Ecology	Transpiration	LICOR 6400XT Infrared Gas Analyzer (IRGA)	Direct, leaf-level measurements
	Climate	EarthNetworks and MCFDX meteorological stations	Data access/download
Biogeochemistry	Soil moisture	ONSET 10HS soil moisture smart sensor	Automatic data logger

Authors (2020)

We collected stormwater samples from the ISCOs within 12 h of each event and processed them in ASU's Wetland Ecosystem Ecology Lab. Subsamples for dissolved organic carbon (DOC) and anion analysis were filtered through ashed Whatman GF/F® 47 mm filters, and DOC samples were HCl-acidified to pH = 2. DOC samples were analyzed within 7 days on a Shimadzu TOC-VC/TN analyzer (detection limit, 0.04-mg DOC/L and 0.004-mg TN/L). Unfiltered subsamples were collected for total nitrogen (TN) and total phosphorus (TP). Nitrate (NO_3^-), nitrite (NO_2^-), and ammonium (NH_4^+) samples were centrifuged to remove particulates and, along with TN and TP, were analyzed on a Lachat Quickchem 8000 Flow Injection Analyzer (detection limit, 0.85-μg NO_3^--N/L and 3.01-μg NH_4-N/L). The studies developed at The Central Arizona–Phoenix Long-Term Ecological Research (CAP LTER) (https://sustainability.asu.edu/caplter/)-a long-term urban ecological research project, stormwater sampling protocols to provide cross-site comparability.

11.2.5 Hydrology

To determine effluent discharge volumes from the basins, 90° V-notch weirs were constructed and installed at the outflow discharge points of the east and west basin systems (Fig. 11.1). ONSET HOBO U20L water-level probes were installed 10 cm upstream from the weirs inside the discharge pipe/channel to measure the water stage. We used the US Bureau of Reclamation (2001) cone equation for V-notched weirs to calculate discharge rates through the weirs:

$$Q = 2.49\,h_1^{2.48}$$

where Q was the flow rate ($m^3\ sec^{-1}$), and h_1 was the hydraulic head on the weir (m).

11.2.6 Soil Moisture

In addition to water quality and flow, soil moisture was identified in the design co-production process as a useful metric for the Orange Mall UEI as an estimate of the ability of the bioretention basins to provide passive irrigation to the vegetation planted in them. We measured the soil moisture content at 15 cm depth in the largest EB1 and EB2 basins (Fig. 11.1) using ONSET HOBO 10HS Soil Moisture Probes and an ONSET USB Micro Station Data Logger; the probes captured soil moisture data at 5 min intervals (ONSET HOBOWare Version 3.7.15, ONSET, Bourne, MA). Soil moisture readings were averaged across all sensors within a basin as basin soil amendments were identical.

11.2.7 Transpiration

Orange Mall managers were also interested in understanding relative transpiration rates for the various species of vegetation planted in the basins, given the important implications this has for plant water use efficiency, soil moisture dynamics, and microclimate mitigation. We measured the leaf-specific transpiration rates for the five dominant macrophyte species planted throughout the system: Arizona Ash (*Fraxinus velutina*), Tall Slipper Plant (*Pedilanthus bracteatus*), Common Sotol (*Dasylirion wheeleri*), Mexican Petunia (*Ruellia brittoniana*), and Jojoba (*Simmondsia chinensis*). Gas flux data were collected using a LICOR LI-6400 handheld infrared gas analyzer (IRGA) in 2–3 h mid-day sampling sessions on randomly selected individuals of each species across all basins and on three leaves representing the height and width of the plant canopy. Transpiration measurements were made every other day for a week after each rain event and biweekly between storm events.

11.2.8 Meteorological Data

We determined storm intensity and duration using daily rainfall data from a Maricopa County Flood Control District rain gauge located 0.6 km south of Orange Mall (Station ID: 67500 – ASU South), as well as data from a ASU EarthNetworks meteorological station located 0.3 km northeast of Orange Mall (Station ID: TMPST). We averaged rainfall data from these two stations to estimate precipitation at Orange Mall, located roughly halfway between the two stations. These data were used to characterize each storm event and in terms of the timing, amount, and intensity of rainfall.

11.3 Results and Discussion

11.3.1 Understanding the Design Process

A number of authors have called for the co-production of the design process (Childers et al., 2015; Grove et al., 2016), but there are few examples in the literature of this process being applied effectively. A review by Trencher et al. (2014) demonstrated the value of university partnerships for urban co-design and co-production processes. The research we present here is an actual on-campus example of such a partnership. Our approach to this design co-production process mirrored the framework of Polk (2015). Our observations and interviews yielded a number of important insights into the design process. We observed five monitoring design planning meetings and conducted 12 interviews, with two researchers and 10 practitioners. The final codebook used for the qualitative data analysis contained five top-level themes: previous experience, design process, challenges, opportunities, and outcomes (Table 11.2). This design process section begins with the narrative and overall dynamics of monitoring protocol development, followed by more specific data from interview themes.

11.3.2 Defining and Understanding

The UEI concept was not inherently new for project participants. All of the practitioners who were interviewed expressed previous experience with the designing, managing, or researching of UEI features. However, the practitioners referred to UEI as either green infrastructure or nature-based solutions, as these are the terms and concepts primarily used by the landscape architecture profession. Common themes included an emphasis on ecological structures (e.g., bioswales, wetlands) and functions (e.g., stormwater capture, water quality improvement, microclimate

Table 11.2 Top-level codes and subcodes used for coding analysis

Top-level codes	Description	Example subcodes
Previous experience	Descriptions and anecdotes of previous experience working with UEI	Education, professional experience, solutions, definitions, monitoring
Design process	Descriptions and anecdotes about the Orange mall site and research design	UEI drivers, UEI challenges, SITES
Challenges	Content related to challenges associated with monitoring UEI	Time, funding, institutional, organizational
Opportunities	Content related to opportunities associated with monitoring UEI	Evidence, education, time
Outcomes	Outcomes and results as a result of co-production experience	Individual learning, institutional learning, sustainability, evidence

Authors (2020)

mitigation). Notably, their definitions did not contain references to the more enviro-political definition of green infrastructure (e.g., solar panels, recycling bins) noticeable in the US literature but not globally.

Interestingly, practitioners often cited the use of UEI in previous work experience, mainly in private consulting landscape design projects. They noted an intuitive orientation toward UEI-based solutions, such as bioswales or infiltration basins, to manage flooding issues, but without reliance on strong research-based evidence to inform these designs. This was directly attributed to (1) a lack of peer-reviewed evidence of site-scale UEI performance, (2) unfamiliarity with or inability to access researchers or peer-reviewed literature, or (3) reliance on established designs and precedent. Three-quarters of practitioners interviewed reported using UEI-based techniques as part of common practice in the “field” [of landscape architecture] to achieve design solutions that were both aesthetically pleasing and functional.

The researchers we interviewed were familiar with the UEI concept, which they attributed to their involvement with urban research programs such as CAP LTER. All researchers had previous experience as practitioners, including experience that spanned both private and public practices. In some cases, these experiences included projects focused on the monitoring of UEI using designed-experiment research approaches (sensu Felson & Pickett, 2005).

11.3.3 Design Process

The decision to implement ecohydrological monitoring of the Orange Mall UEI features emerged late in the process. Initially, the focus of the monitoring was on attaining SITES certification as a vehicle to formalize existing practices encouraging more sustainable and resilient landscape features on campus. At this point the practitioners decided to engage with researchers to meet the SITES monitoring goals. The collaborative meetings among researchers, key ASU practitioners, and external consultants involved in the design and management of Orange Mall began in Spring 2018. These workshop-style discussions, focused on co-producing a monitoring protocol, included a review of the site design history, SITES documentation and mandates, availability of resources (e.g., equipment, staff time, funding), and related research interests.

In these collaborative meetings, we vetted the types of data that would be most interesting or valuable for evaluating site performance and applying for SITES certification. Importantly, these conversations were framed to ensure that practitioners and researchers were equal partners, so that everyone involved had genuine agency in the design process. Practitioners indicated that they were primarily interested in stormwater quality and quantity data to meet SITES reporting requirements. In response, we presented them with a suite of different methods that should be used to achieve the goals of both researchers and practitioners. Importantly, we as researchers were all affiliated with CAP LTER, which already had existing sampling designs and protocols for monitoring stormwater UEI in Phoenix (e.g., Hale et al., 2015). With this as a start, the group was able to decide on a final suite of metrics, equipment, sampling, and analytical techniques to evaluate the performance of the Orange Mall UEI (Table 11.3). As the monitoring and sampling protocols were being finalized, printed copies of the Orange Mall final site plans were used as collaborative tools to map expected stormwater hydrology in the bioretention basins, to sketch different sampling scenarios, and to finalize equipment locations in response to a number of constraints (e.g., water flow dynamics, safety and ADA compliance, aesthetic concerns). These interactive drawing sessions proved to be a particularly popular and effective method to communicate and collaborate.

11.3.4 Challenges

Throughout this process, three key limitations to an optimal monitoring design arose—funding, aesthetics climate (Table 11.2). To the first challenge, SITES-focused monitoring was not included in the plan or budget for the Orange Mall redevelopment project, so the Office of the University Architect did not have resources to purchase monitoring equipment or pay for sample and data analyses. We overcame this challenge by volunteering the use of existing sampling equipment

Table 11.3 Key themes and quotes: challenges and opportunities associated with the design co-production and monitoring of UEI. (Authors, 2020)

Category	Theme	Example quotes
Challenges	Arid cities	”One of the things that, I think, we’ve discussed in the past is this idea that here they don’t get tested very often. There’s not even a—if you have a bioretention basin, the chances of them actually seeing it working are really low.”
	Institutional	“You know, it was overwhelming. I’m not an engineer, but I mean I kept talking to the engineer and like, “This is what I want to do.” [Then he said] “Yeah, yeah, yeah, but that’s not how we do it.” “[Contractors] are actually more integral…in ways that you don’t really think about until it’s too late. For example, not on the Orange Mall Project, but on the Nelson Project, which is also on campus. We just were not collaborative enough and there was a breakdown in communication.”
	Resources	“[Usually] there’s no money, no time to even think about monitoring long-term, or really understanding how it perform. We will go back to the site to see, “Oh, wow, this is our design. Cool!
Opportunities	Evidence	“This Orange Mall project provides a really cool opportunity to do that for this type of landscaping because there’s this intuitiveness of oh, yeah, we should use infiltration basins. Now there’s a chance to actually test that and use that as evidence going forward.”
	Education	“Here especially at ASU, we have a huge educational component. So to be able to demonstrate that in a very public and open way is—was also a very interesting and exciting benefit.”

and leveraging supplemental funding from CAP LTER for new equipment and sample analysis costs.

The second challenge was to accommodate aesthetics and security of monitoring equipment onsite. ASU practitioners stressed their excitement about highlighting actual research occurring on campus while also emphasizing that the visibility and appearance of research equipment must be minimized and, where equipment could not be hidden, that it must blend in with the overall site aesthetics. The main issue here was where to house the large ISCO autosamplers, which had to be located onsite. The collaborative solution was to house them in box-like enclosures that closely resembled the trash and recycling receptacles already onsite (Fig. 11.5). That problem solved, ASU practitioners then chose to install interpretive signage on these bins, which also earned additional SITES credits for education and awareness efforts. These interpretive signs raised awareness of the campus-wide value of both UEI approaches, such as the Orange Mall project, and of ongoing research efforts around them.

Finally, nearly all participants spoke to the challenges of monitoring stormwater UEI in an arid context. As an example, one participant noted that "here [UEI features] don't get tested very often…if you have a bioretention basin, the chances of actually seeing it working are really low." Infrequent rain events (average annual rainfall in Phoenix is 20 cm) and high inter-annual variability in rainfall can significantly impact the quantity of monitoring data and results. For example, while we were able to capture four storms in this study that were intense enough or of long enough duration to produce flow through the Orange Mall bioswale system, this same location received virtually no rainfall during the same time period (August to February) in the previous year (2017–2018; Maricopa County Flood Control District 2019) and similarly received no rainfall between early March and early December in 2020.

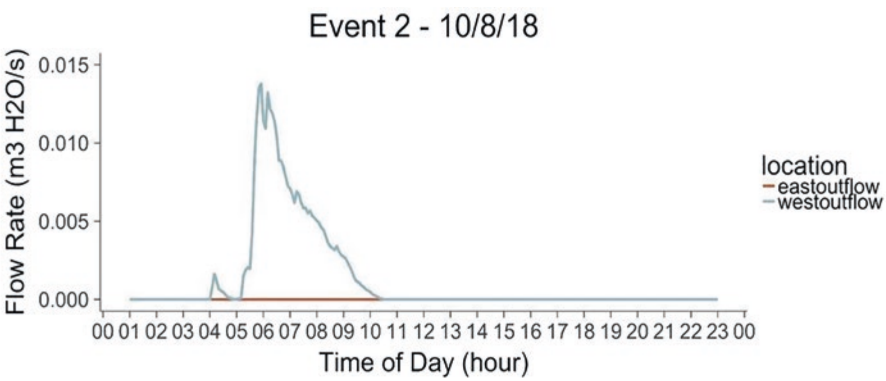

Fig. 11.5 Instantaneous discharge rates from the east outflow and west outflow drainages recorded in two events; note that the storm did not reach threshold strength or intensity to fully activate the east drainage system. (Authors, 2020)

11.3.5 Opportunities and Outcomes

Our study of the monitoring design process revealed a number of positive opportunities associated with monitoring UEI (Table 11.3). All participants had challenges finding evidence of how aridland stormwater UEI performs; thus they viewed this co-production process as a critical opportunity to generate such evidence. Practitioners at ASU and the external consultants were enthusiastic about using these data to support more effective future UEI design and management. One response was particularly revealing: a practitioner stated that "this Orange Mall project provides a really cool opportunity to do [monitoring] for this type of landscaping because there's this intuitiveness of oh, yeah, we should use infiltration basins. Now there's a chance to actually test that and use that as evidence going forward."

We also observed evidence of learning and significant improvements in institutional capacity (Table 11.3). One practitioner summarized it well: "We all, as a team, didn't see the pieces [of this project] and where they needed to go, and now I understand it." This practitioner was referring to understanding all of the various components and processes associated with the monitoring of a UEI project. As a result of their co-production experiences with the Orange Mall project, practitioners repeatedly emphasized an improved ability to support the incorporation of monitoring into the planning of future projects. As researchers, we also became much more fluent in understanding and navigating the design process. This included the ability to work with planning and engineering disciplines and documents and to anticipate the needs and concerns associated with conducting research at high-traffic, high-profile locations.

Finally, several important educational opportunities emerged from this UEI monitoring project. As one ASU practitioner described it, "to be able demonstrate [UEI] in a very public and open way was also a very interesting and exciting benefit." ASU practitioners described how participation in this collaborative project increased their awareness of how high-profile monitoring and research efforts on campus can enhance student engagement through interpretive signage as well as by actively engaging faculty and students in on-campus research and monitoring activities.

11.3.6 Design Outcomes

Another key goal of this project was to understand how the stormwater UEI at Orange Mall performed. We implemented the co-produced monitoring protocol, and here we report on the first 7 months of data collection (August 2018 to February 2019); as of December 2020, the system was still being monitored as part of the CAP LTER long-term research portfolio. In this section we present these ecohydrologic and biogeochemical data and our interpretations of design performance outcomes.

11.3.7 Mitigating Storm Events

During the 7 month study period, the Orange Mall site experienced 17 rain events. Only four of these storms fully inundated the basins to achieve flow throughout the system and activate the ISCO samplers (Table 11.4). We determined that the threshold for full activation of all basins was a storm intensity of 0.76 mm h^{-1}. Less-intense events partially inundated the basins but did not achieve flow among basins and thus did not activate water sampling. This varied with basin location, size, and design: the west basins flooded faster and had one more event sampled for water quality than the east basins.

The first storm to fully inundate and achieve flow among the Orange Mall UEI basins on 19 September 2018 produced 3.00 mm of precipitation in 1 h (Table 11.4). Water outflow rates from the east and west basins peaked at 0.043 m^3 s^{-1} and 0.75 m^3 s^{-1}, respectively, with an estimated 1.379 m^3 of total outflow from the storm event. The second storm to produce flow, on 8 October 2018, generated 5.1 mm of precipitation over 3 h, for a storm intensity of 1.69 mm h^{-1} (Table 11.4). The outflow rates from the west basins peaked at 0.45 m^3 s^{-1}, for an estimated total outflow of 0.86 m^3. This storm event did not produce measurable outflow from the east basins (Fig. 11.1). The third and largest storm that occurred, on 13 October 2018, produced 18.8 mm of precipitation over 7 h, for an overall storm intensity of 2.7 mm h^{-1} (Table 11.4). The resulting discharge from the east and west basins peaked at 0.38 m^3 s^{-1} and 0.18 m^3 s^{-1}, respectively, for an estimated 1623.1 m^3 of total outflow from the storm event (Fig. 11.6). The final storm, on 16 January 2019, generated 5.1 mm of precipitation over 3 h, for an overall storm intensity of 1.7 mm h^{-1}. The discharge from the east and west basins peaked at 0.21 mL^3 s^{-1} and 2.32 m^3 s^{-1}, respectively, with an estimated 14.801 m^3 of total outflow occurring during the event.

Table 11.4 Characteristics of storms sampled in this study. (Authors, 2020)

Storm ID	Date	Total precip (mm)	Duration (h)	Intensity (mm h^{-1})
1	9/19/18	3.00	1	2.9
2	10/8/18	5.08	3	1.69
3	10/13/18	18.79	7	2.68
4	1/16/19	3.05	4	0.76

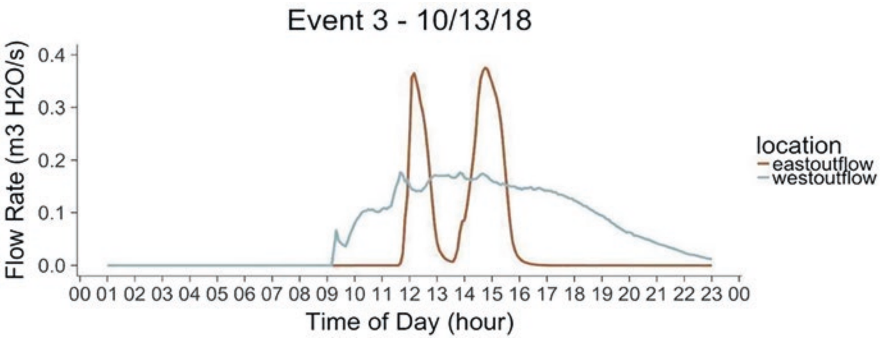

Fig. 11.6 Instantaneous discharge rates from the east outflow and west outflow drainages recorded in two events; note that the storm did not reach the threshold strength or intensity to fully activate the east drainage system. (Authors, 2020)

11.3.8 Improving Water Quality

While we presented individual water quality data for each storm separately to our practitioner colleagues for the SITES application, for this analysis, we averaged the data across all four storm events to better understand how the Orange Mall UEI system performed across a variety of storm events. In order to better understand how the bioretention basins processed stormwater, we calculated upstream-downstream change for each water quality analysis in each basin system; a positive concentration change meant that the bioretention basins were sources of a constituent to the stormwater in the system.

As expected, the dissolved nitrogen constituents showed different patterns of uptake or release when compared with the particulate-dominated constituents. Across the four storms, nitrate (NO_3^-) concentrations ranged from 0.02 to 1.71 mg L^{-1}, and ammonium (NH_4^+) concentrations ranged from 0.01 to 0.31 mg L^{-1}. Ammonium behaved differently in the upstream east basins (EB 1 and 2) and the downstream east basins (EB3 and 4). Across all storms, the former were a consistent sink for NH_4^+, whereas the downstream basins showed little to no NH_4^+ flux (Fig. 11.7). We saw the opposite pattern for the three basins in the west basins, which were a source of NH_4^+ during the first hour of full inundation but showed little net flux after that point. There was an initial flushing of NO_3^- from all three systems, during the first 15 min of inundation, after which the downstream east basins and the west basins continued to release NO_3^- into the stormwater, whereas the upstream east basins became a strong sink for NO_3^- (Fig. 11.7).

In a more comprehensive study of stormwater dynamics in Phoenix, Arizona, USA, Hale et al. (2014) reported consistent uptake of inorganic nitrogen from stormwater runoff, which we did not observe. However, their research included multiple nested stormwater sheds, all considerably larger than ASU's Orange Mall UEI system. Shetty et al. (2018) studied nitrogen cycling in seven stormwater bioswales in New York City, USA, and concluded that the ability of the bioswales to

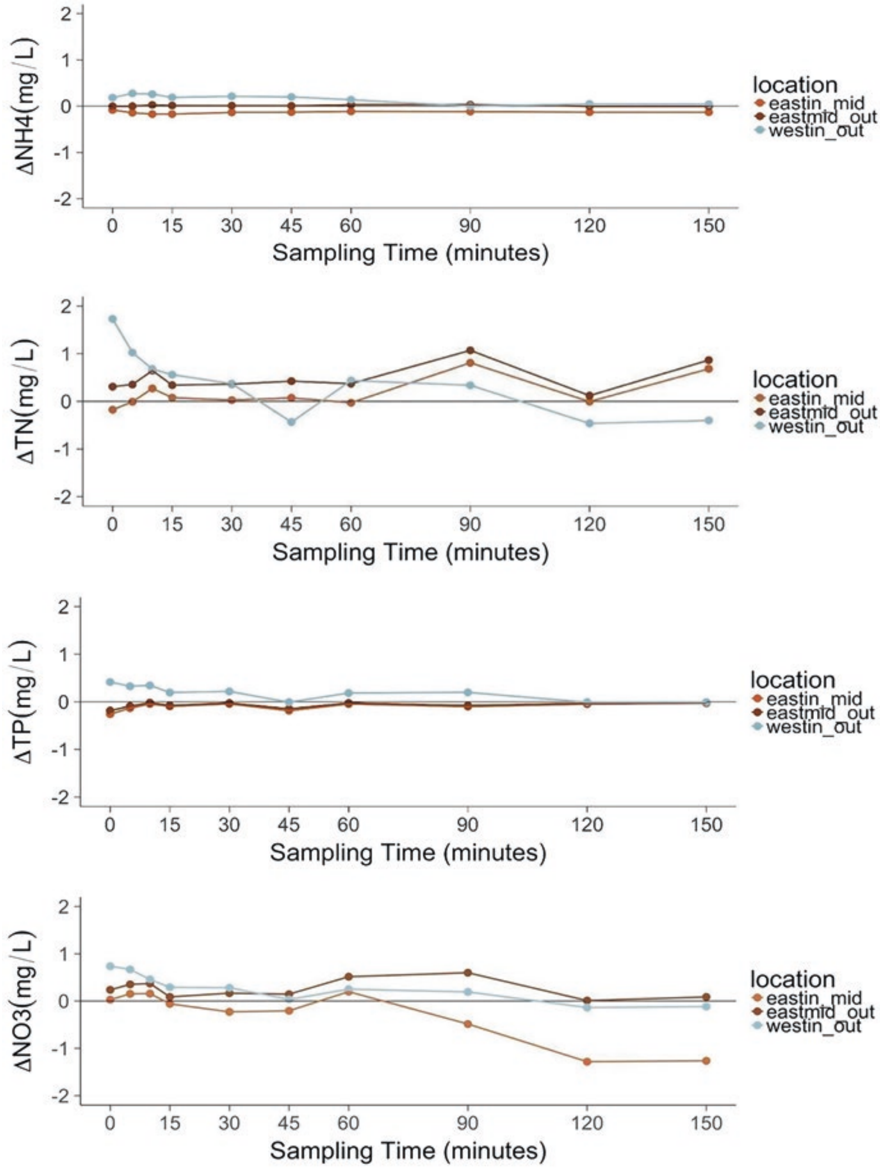

Fig. 11.7 Average change instantaneous discharge rates from the east and west outflow drainages recorded in two events; note that the storm did not reach the threshold strength or intensity to fully activate the east drainage system. (Authors)

process stormwater inputs of nitrogen was strongly controlled by the amount of nitrogen and organic matter in the soils. They recommended that bioswale soils be as nitrogen and organic matter deficient as possible and that they not be fertilized.

Across all storm events, the total nitrogen (TN) concentrations ranged from 0.35 to 3.17 mg L^{-1}, and the total phosphorus (TP) concentrations ranged from 0.06 to 0.59 mg L^{-1}. Assuming both TN and TP were made up largely of particulate-bound nutrients, we expected to see a net uptake of both due to settling and with greater uptake later in the storms as water residence times increased. This was not the case. The entire east drainage system was a consistent source of TN to the stormwater, and the west drainage was a TN source – including a large initial flush of TN – until the end of the storm events (Fig. 11.7). We observed a more curious pattern with TP, where the entire east basin system was a small sink, whereas the west basin system was a source of TP to the stormwater (Fig. 11.8). This divergence in behaviors may be related to the fraction of total N and P that was in dissolved organic forms versus associated with particles. Unfortunately, the samples were not analyzed for dissolved organic N or P. The dissolved inorganic N fraction of TN (i.e., NO_3^- and NH_4^+) ranged from 10% to 64%, suggesting that the amount of particulate-bound N was quite variable in both time (across the storms and within a given event) and space (across the bioretention basins).

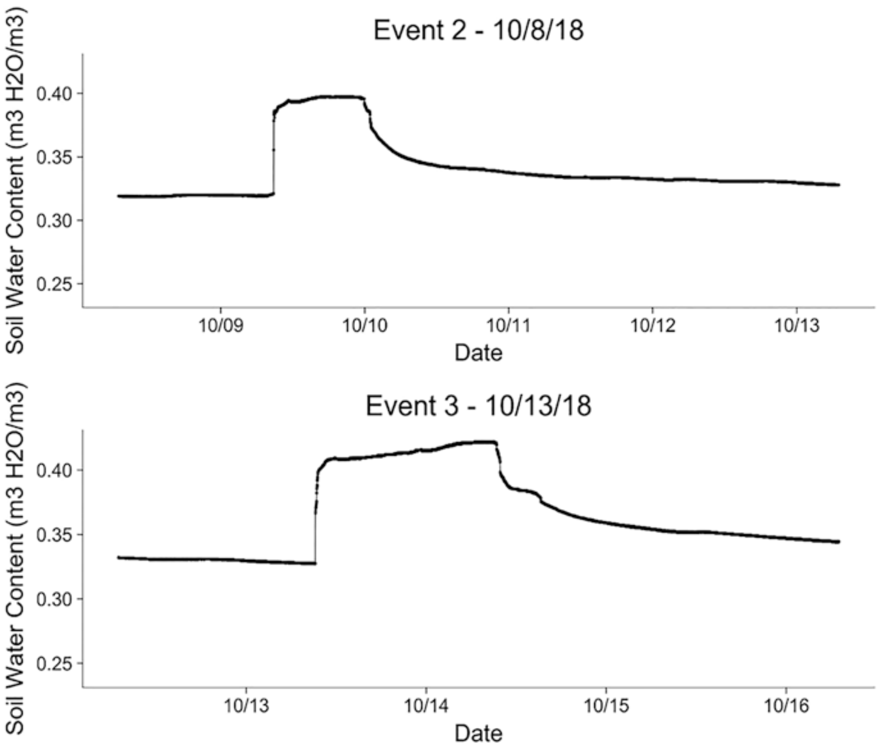

Fig. 11.8 Soil moisture in the bioretention basins during and after the storm event for Event #2 and Event #3. (Authors)

We were not able to calculate actual fluxes of these nutrients either into the stormwater, when the basins were sources, or from the stormwater, when the basins were sinks. Stormwater inflows to all of the basins were nonpoint source runoff, which we could not quantify. We do have water flow data from the downstream-most points of both the east and west basins, which would allow us to calculate nutrient fluxes out of the system when storms exceeded the design capacity of the basins. But these data were not sufficient to calculate nutrient budgets for the basins.

11.3.9 The Role of Soils and Vegetation in Adaptive Design

Volumetric soil water content is an important measure of the ability of bioretention basins to absorb runoff before they saturate and begin to fill with stormwater. When soils are holding less water before a storm event, they theoretically should be able to absorb more runoff at the beginning of a storm. The baseline soil moisture content in September (event #1; data not shown) was 0.24 m^3 H_2O m^{-3}. It peaked at 0.37 m^3 H_2O m^{-3} during the storm and took 7 days to return to baseline after the event. For the other three rain events, the baseline soil moisture was higher (0.33 m^3 H_2O m^{-3}), and for the two storms in October, it peaked at 0.39 or 0.42 m^3 H_2O m^{-3} with returns to baseline taking only 4 to 5 days (Fig. 11.8). We saw a similar pattern of soil moisture dynamics during the January storm (event #4; data not shown), with a return-to-baseline condition in only 7 days despite considerably lower air temperatures relative to September–October.

In a stormwater retention basin study conducted in Phoenix, Arizona, USA, Larson and Grimm (2012) showed that the cycle of drying, wetting, and drying of soils in these basins enhanced complete nitrogen removal by coupling nitrification, in dry aerated soils, with denitrification in waterlogged post-storm soils. Morse et al. (2017) conducted a similar study, but in two retention basins with continuously saturated soils and two where soils regularly dried. They reported that the wet basins were capable of denitrifying 58% of the inorganic nitrogen inputs from stormwater while the dry basins denitrified only 1%. Clearly, more research should be dedicated to the links among hydrology, soil moisture dynamics, and nitrogen cycling in bioretention basins.

We found a general increase in transpiration by the dominant Orange Mall vegetation species following all storm events. Mid-day transpiration rates measured in the days following storm events, when the soil moisture was relatively high, were on average higher than those taken during baseline soil moisture conditions, prior to storm events. However, we did see considerable variation among species: Arizona Ash (*Fraxinus velutina*) transpiration rates increased an average of only 46% following a storm event, while transpiration rates by Tall Slipper Plant (*Pedilanthus bracteatus*) increased by 76%. We expected this result because the Arizona Ash is a native that is well adapted to low water environments, and because of its high water efficiency, its transpiration rates should not increase dramatically when the soil moisture levels are higher. In contrast, Tall Slipper Plant is a succulent that stores and transpires more water when it is available.

We were not able to scale our transpiration measurements to approximate a whole-system water budget. Well-established phenometric models for the species present at Orange Mall do not exist, making biomass estimates very difficult. Further, the leaf structures for many of the species were not conducive to estimating leaf area, which is an alternative approach for scaling leaf-level transpiration rates. Further research to effectively scale transpiration rates in both space and time would contribute to a clearer understanding of the role of vegetation relative to the whole system water budget (Sanchez et al., 2016).

Brodsky et al. (2019) used a holistic ecological approach to investigate plant-soil-microbe-biogeochemistry connections in bioswales in New York City. They found wide variation in transpiration rates among plants, which was expected. However, they also found that plant physiology (e.g., transpiration and growth rates) also had an effect on the soil microbial communities, which in turn affected the ability of the soils to sequester and process nitrogen. They concluded by recommending that plant species palette selection for stormwater UEI be based on the functional consequences of plant-microbial associations.

Finally, the results revealed that the site was able to manage a 25 year storm event compared with the designed intention to retain a 10 year storm event. The combined ecological functions from soil infiltration and plant transpiration have implications in increased stormwater capacity. Soil and vegetation serve as integral parts of the UEI design and are fundamental to landscapes. Designing for increased adaptive capacity in landscapes is critical to address climate change-induced flooding and enhance urban resilience in cities (Ahern, 2011; Cheng et al., 2017).

11.3.10 UEI System Performance

Overall, we found that the system met stormwater management design goals. The majority of the events that occurred at the Orange Mall site, 13 of 17 in total, were not intense enough to cause flow between the basins. For these events, the system captured runoff within each individual basin and managed stormwater through vertical flow paths (infiltration, then evaporation/transpiration). With regard to water retention, on average, soil moisture took just an average of 5.8 days following an event to return-to-baseline conditions; much of this rapid return was due to increased post-storm transpiration by the vegetation. This means that the basins were prepared for the next rain event in less than a week, and this was tested by the 13 October 2018 storm, the largest we observed (1.9 cm of rain in 7 h), which came only 5 days after a 0.5-cm storm.

It is worth noting that stormwater quality is only a regulatory issue for storms of sufficient size that the bioretention basins fill, connect, and lead to outflows from the entire system. This happened in fewer than 25% of the events we documented. Our water quality results from those larger storms were more equivocal, however. In most cases, the basins were either sources of both dissolved and total nutrients, or were temporary or minor sinks for them. In short, there was little evidence that the bioretention basins were sufficiently sequestering nitrogen and phosphorus. This may have been because we began our stormwater monitoring shortly after construction of the Orange Mall bioretention system. The soils likely had not yet stabilized, and the vegetation was clearly still getting established. We are continuing our ecohydrologic sampling, though, and will be able to test this legacy question in the future.

Our results indicated that the co-production process that designed the monitoring approach for Orange Mall resulted in important learning outcomes for both the practitioners and the researchers. Our ecohydrologic data demonstrated that the system met the design goals for managing designed storm event onsite and partially met the design goals for storm water quality improvement. This outcome allowed our practitioner collaborators to successfully apply for SITES certification for the project.

11.4 Conclusions

This study documented the design process, including challenges and opportunities associated with the co-production of UEI monitoring and performance outcomes. Challenges included resources (time and money) and institutional capacity to support engagement between researchers and practitioners. Important positive outcomes and opportunities from the co-production process included (1) a stronger mutual understanding between researchers and practitioners, (2) enhanced practitioner capacity to engage with and support research design, and (3) increased researcher capacity to navigate the design process and anticipate practitioner needs and site constraints. This resulted in what practitioners described as “carryover,” where the experiences, knowledge, and evidence from our Orange Mall collaboration will inform and is informing better design processes in future projects. For example, our monitoring results are feeding back into better design of the UEI itself in the form of improved designs for future projects. This feedback loop serves as an adaptive design approach to achieve resilient outcomes (Ahern, 2011, 2013).

Our research also contributes to a better understanding of UEI performance in aridland urban settings. The collaborative relationships that our group formed is an important first step to more deeply integrating UEI into landscape design. Continuing to develop these relationships between researchers and practitioners is an important next step to improving institutional capacity and building better mutual understanding and trust around the use of research and monitoring in understanding UEI performance. Feedback from case studies and evidence from existing projects will enable more informed exploration of design scenarios for future UEI projects. The increased social and ecological adaptive capacity is key for a resilient landscape and green infrastructure design in order for cities to cope with climate change.

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Chapter 12
Building Other Landscapes: Renaturing Cities

Camila Gomes Sant'Anna

Abstract In the context of the European community, green infrastructure emerged as a tool for planning the landscape in the face of a series of significant contemporary imperatives. Its implementation in Spain, for example, took place through strategies for the renaturalisation of cities aimed not only at environmental conservation, but also at fostering sustainable urbanisation adapted to climate change. In the case of Barcelona's territory, its design is multiscale and translated into green corridors at the regional scale and the greening of 'opportunity areas', mostly unoccupied ones, of different types and sizes at the local scale. Beyond this perspective, physical and ecological connectivity is favoured, ensuring not only biodiversity, but also art, agricultural production and leisure improvements are discussed. The objective of this chapter is to understand how green infrastructure strategies have been incorporated into Barcelona's territory; for this purpose, the methodological implementation strategy, from the regional to the local scale, undergoes analysis. Out of this process arise considerations of a new green and productive metropolitan development paradigm, known as green infrastructure.

Keywords Landscape · Green infrastructure · Renaturing cities · Hybrid infrastructures

In the context of the European community, green infrastructure emerged as a tool for planning the landscape in the face of a series of significant contemporary imperatives. Its implementation in Spain, for example, took place through strategies for the renaturalisation of cities aimed not only at environmental conservation but also at fostering sustainable urbanisation adapted to climate change. In the case of Barcelona's territory, its design is multi-scale and translated into green corridors at the regional scale and the greening of 'opportunity areas', mostly unoccupied ones,

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of different types and sizes at the local scale. Within this perspective, physical and ecological connectivity is favoured, ensuring that not only biodiversity but also art, agricultural production and leisure improvements are discussed. The objective of this chapter is to understand how green infrastructure strategies have been incorporated into Barcelona's territory; for this purpose, the methodological implementation strategy, from the regional to the local scale, undergoes analysis. Out of this process arise considerations of a new green and productive metropolitan development paradigm, known as green infrastructure.

12.1 Introduction

Green infrastructure (GI) has been the subject of numerous academic studies and policies developed by international agencies to aid technical cooperation and delivery. Each uses the theoretical discourse surrounding GI, as discussed by Mell and Clement (2020), as a way to design for climate change, promoting a renaturing of cities that ensures ecosystem services, ecological resilience and the creation of connected and equitable landscapes. In this chapter, GI is understood to be the planning and design of the landscape of a territory in an integrated way, structuring and connecting its green and blue systems and valuing its material characteristics (urban occupations, vegetation, water bodies, soil characteristics and fauna and flora), as well as its intangible ones (aesthetics, culture and heritage) (Sant'Anna, 2020: 101). Therefore, landscape planning with GI:

> [...] entails a design vision that translates planning strategy into physical reality while heeding the ecological and cultural characteristics of a particular locale – whether a region or individual building site. It is, by necessity, an approach that involves aesthetics: what a place should look like as informed by the people who live on the land, their past, and their aspirations. (Rouse and Bunster-Ossa, 2013: 174)

The basis for the development of this form of planning is the regional scale, as it allows for an elevation of thinking regarding the ecological matrix of metropolitan areas to a number of scales (global, regional and local) (Battle, 2011). At the regional scale, according to Rouse and Bunster-Ossa (2013), each zone of GI assumes a different spatial translation:

> [...]green infrastructure in rural contexts corresponds to either the Rural Preserve (as wilderness) or to the Rural Reserve (as "working lands with conservation value" [Benedict and McMahon, 2006]). In more-developed suburban contexts, green infrastructure takes on forms such as nature preserves surrounded by development, parks with active recreational facilities, and private gardens. Green infrastructure merges with the built environment in dense urban contexts (Urban Center and Urban Core), where it is expressed in streetscapes, urban parks and public gathering spaces, green stormwater infrastructure, and so on. (Rouse & Bunster-Ossa, 2013: 23)

The first methodological strategies for landscape planning and design with GI were initially developed in the US states of Florida and Maryland in 1994. There, Greenways Planning Initiatives proposed the implementation of a statewide greenway system. This proposal aimed to connect a set of existing GI elements, whether at the local or regional scale, with the structuring of "conservation lands, trails, urban open spaces, and private working landscapes" (Benedict & McMahon, 2006: 35).

Initially, GI strategies focused on reviewing more traditional environmental conservation actions, engaging primarily with protecting areas of environmental interest – especially those that are part of green corridors – with less discussion of their role as multifunctional urban infrastructure capable of guiding a territory's landscape planning (Firehock & Walker, 2019; Rouse & Bunter-Ossa, 2013).

However, European experiences, which are comparable to North American ones, have used a systemic approach that takes into account additional dimensions of the landscape, be they social, cultural, economic or ecological. Within this context, albeit recently, the Spanish experiences have been developed as regional and local strategies, updating landscape planning and design by incorporating concepts, such as the garden city and green belts, to meet contemporary demands of adaptation to climate change. Therefore, they were taken as the subject of a case study in the following chapter.

The purpose of this chapter is to better understand how the methodological discussions of landscape planning and design have incorporated GI and under what values they are consolidated in the territory of Barcelona's metropolitan region. This reflects on the idealisation of the sociocultural and ecological network and moves on to examine its reverberation in terms of urban design at a local scale in the city of Barcelona.

12.2 Green Infrastructure in the Construction of Resilient and Equitable European Landscapes

To frame the discussion in Barcelona, it is important to locate GI geographically in a European context in order to assess local-level action. The European Commission defines GI as:

> a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. It incorporates green spaces (or blue if aquatic ecosystems are concerned) and other physical features in terrestrial (including coastal) and marine areas. On land, GI is present in rural and urban settings. (European Commission, 2013: 4)

This definition of GI – still focused on its ecological contribution – influenced the initial understanding of the concept as an innovative strategy for environmental conservation, taking into account the loss of biodiversity, especially related to climate variations:

> When appropriate, such approaches use GI solutions, because they use biodiversity and ecosystem services as part of an overall adaptation strategy to help people adapt to or mitigate the adverse effects of climate change. (European Commission, 2013: 4)

In this context, according to the European Commission, there was an urgent need to scientifically explore the concepts, principles and methodologies of urban, peri-urban and rural planning associated with GI to assess its contribution and integrate it into the agenda for managing the risk of natural disasters and adaptation to climate change (European Commission, 2015). The debate on GI in Europe then started to address sustainable strategies on multiple scales. In 2013, in order to define a European Green Infrastructure Strategy, the European Union established two complementary work groups, which responded to the environmental and urban agendas: the *European Green Infrastructure Policy* and the *Nature-Based Solution (NBS)* groups. In the beginning, the NBS came out of the GI debate as a concept to define the urban elements of GI, but nowadays its position in Europe is very different.

The first group aimed to build an understanding of how GI planning could be implemented. The second was tasked with mapping, developing and disseminating the evidence supporting NBS to translate this into projects and GI strategies, especially with regard to their dialogue with existing traditional grey infrastructure. Consequently, there is an understanding that 'NBS have an important role to play, for instance, through supporting the implementation and optimization of green, blue and grey infrastructure' (European Commission, 2015:18).

In response to this, guidelines and projects that focused on GI were proposed, supporting a view of landscape planning and design that expands upon the initial perspective centred on biodiversity into a more holistic view, engaged with socio-cultural values. Thus, although the rationale for GI planning was based on natural processes, it should also be thought of as a 'place-based' approach, promoting green urban-economic development and, at the same time, conserving the natural values of the place (European Commission, 2013).

However, most of the proposals that emerged to date have guidelines for implementing GI that remain very general and technical, centred on physical and ecological connectivity. The specific territorial context may not be considered in a systemic and multi-scalar approach for analysis, thus failing to account for their specific characteristics in terms of development in line with nature and culture. GI has emerged as a tool to build connected and equitable landscapes. Thus, it provides an opportunity to translate the desire for environmental justice and liveable spaces into reality.

Nonetheless, even though there is considerable knowledge exchange between various European countries on the theoretical and practical experiences related to GI, the planning and design of the landscape ends up being constrained by the political-administrative limits of each country, rather than as a consideration of the information about the landscape, for instance, its hydrographic basin.

In addition, there is no consensus on the methodological basis on which landscape planning and design with GI can, or should, be implemented in different locations, in the context of a specific plan or in infrastructure plans of a broader character and its spatial translation in terms of urban design. Concerning the incorporation of landscape planning and design with GI and matching this with the political-administrative boundaries of each country (Spirn, 1995), there remains little consensus. Neither the methodological basis on which it would be implemented and adapted nor the spatial translation in terms of urban design are easily defined. When reviewing the existing European Commission guidelines, it is clear that the definition of which elements comprise GI in the planning and design stages in terms of constraints, processes and success factors remains broadly outlined and has no specific detail on how best to spatialise them. At the national level, particularly in the case of Spain, gaps in methodological strategies have been addressed through the use of a systemic approach that includes multi-scale aspects of planning, ranging from guidelines to landscape design.

12.3 GI Renaturalising the Different Spanish Landscapes

In Spain, renaturing cities is not a new concept. It has been translated into practice over the centuries in different ways, lately with the green corridor and green belt schemes reinforcing the importance of landscape ecology. The development of GI plans is relatively recent (post-2000), but these are now taking off as the result of a partnership between universities, the third sector, communities and the government, as a regional and local strategic partner. In support of this, Tojo (2008,107) proposes infrastructure as an articulating element between ecological networks and city systems (Valladares et al., 2007). The topic of GI has been adopted into national legislation in numerous places in Spain, such as Madrid, Valencia and Vitoria-Gastiez, while it still remains closely linked to the integrated environmental conservation of 27% of the country's protected green space. Following the guidelines on protected natural spaces, primarily linked to the Natura 2000 Network and natural heritage areas protected by UNESCO and World Heritage, Law 33/2015, from 21 September 2015, which replaces Law 42/2007 from 13 December 2007, on Natural Heritage and Biodiversity, reinforces this fact (Chap. III, title I), concerning the State Strategy for GI and ecological connectivity and restoration:

> [...] for the territorial and sectoral planning carried out by public administrations to permit and ensure ecological connectivity and the functionality of ecosystems, mitigation and adaptation to effects of climate change, defragmentation of strategic areas for connectivity and restoration of degraded ecosystems. (SPAIN, 2015, Chapter 3, Art. 15, § 2)

This strategy incorporates the European Commission's guidelines on GI – Enhancing Europe's Natural Capital (2013), giving the municipalities of each Spanish autonomous community a period of 3 years to develop their own GI strategy, taking into account the guidelines of the European Landscape Convention from 2000 (Sanchez, 2018). The definition of a proposal for a GI network adds to the Greenery and Biodiversity Plan and the Spanish National Climate Change Adaptation Municipality Plan, as well as providing protective measures for national and international heritage. Moreover, strategies emerge as a way to promote the process of renaturalisation of landscapes in Spanish cities and the appreciation of the 'green' perspective in the city's urban development:

> The concept of naturalisation has an urban character that starts from intervening in spaces that have been artificialized. Interestingly, it involves human intervention to obtain results in favour of natural processes. On the contrary, artificialization would advance. It could be an acknowledgment from the city that the grey urban plot is excessive for the requirements of human life. The concept of naturalisation, close to ecological restoration, being urban stands out for its social dimension and also for the search for a more ecological aesthetic. Thus, with the ecological processes, human desires and values are mixed. (Pares & Rull, 2019: 277)

Within this perspective of cities' renaturalisation, GI

> […] is not presented as a new figure for the protection of natural heritage, but as an integrating tool that aims to ensure the processes originated in ecological systems and whose benefits revert to the human being (in relation to the increase in the efficiency of natural resources, climate change mitigation and adaptation, disaster prevention, water, soil and land management, agriculture and forestry, investment and employment, health, etc.) (Sanchez, 2018: 52)

Additionally, from regional to local:

> […] on the one hand, to solve the pressures on the environment by protecting the processes that occur in nature as a guarantee of ecosystem services and, on the other hand, to stop the growing loss of biodiversity in its territory; and, to achieve them, it emerges as an ecological network of spaces designed and managed to promote the improvement, maintenance and restoration of ecological connectivity between habitats. […] (Sanchez, 2018: 52-53)

Furthermore, in 2015, a group of specialists met and created a working group that was to think about the methodological strategies for the incorporation of GI as a tool for landscape planning and design. As a result, in 2017 the book 'Scientific-technical bases for State Strategy for GI and connectivity and ecological restoration' was published. However, this book did not articulate how these strategies would be developed, which ended up being the responsibility of each municipality where GI would be implemented. In order to better understand how these methodological strategies could take shape on a regional and local scale, the next section discusses how these strategies occurred in Barcelona – a diffuse metropolis of 3.2 million inhabitants.

From the Plan to the Local Context: The Planning and Design of Barcelona's Green Metropolitan Infrastructure.

The region of Barcelona is located in northeastern Spain on the Mediterranean Sea and is one of the densest regions of Europe. It has 5.04 million inhabitants in an area of 3.244 km^2, 164 municipalities, of which Barcelona (1.61 million inhabitants) is the most important.

The 2017 GI plan and design for the sprawling metropolitan territory consisting of 36 municipalities, including Barcelona, seeks to enhance its rich variety of natural habitats with high ecological value, including the Mediterranean forest (1181, 56 km^2, 36, 5%), by reviewing the physical and ecological connections through its GI network, the urban-rural fringes, and assessing the fragmenting of its green structure by unplanned development. The intention of the plan was to reflect on a holistic design of the territory that also considers the landscape units, nearly 70% of protected environmental interest areas, including, completely or partially, 14 areas of environmental interest to the Natura 2000 network, as well as Spain's sustainable forest management planning areas.

The GI strategy deepens the readings and strategies developed for the elaboration of the Plan del Verde y de la Biodiversidad (2012–2020), which is part of the Metropolitan Urban Master Plan (PDM), also dialoguing with the 2017 Urban Green Infrastructure Impulse Program. This plan foresaw that Barcelona in 2050 would be 'a city where nature and urbanity interact and enhance one another by ensuring the connectivity of green infrastructure'. The plan established 10 strategies that were guided by two main concepts: *renaturalisation* and *physical and ecological connectivity*.

As a consequence, the plan developed from a 'layer cake analysis' of the territory, organised in workshops, which had included participation of the local population in its elaboration and were disseminated through lectures and exhibitions, as can be seen in the most recent exhibition, the itinerant 'Metropolis Verda'. Initially, the readings focused on understanding the geography and history of the territory and the land use process to create a series of thematic maps. Then, the objective was to identify, catalogue and organise the performance of the urban systems of the metropolis, from the analysis of its occupation model, its renewable resources, its efficiencies and the integration of all these attributes, with the help of the tool Territorial Information System for the Network of Open areas in the province of Barcelona (Sitxell, www. Sitxell.eu/en).

A principle of extreme importance that emerges in this analysis is that of 'habitability', understood as the set of physical, sociocultural, economic and psychological values that guarantee the quality of life in the place. From the water perspective, it is possible to observe how this principle, as well as the other values presented, is considered. The treatment of the data seeks to indicate possible directions, the mapping of biodiversity hotspots and where it would be interesting to promote GI to expand the potential functionality of Barcelona's urban metabolism.

After all the layers of thematic analysis had been superimposed, the next step was to think about the territory at different scales: its environmental matrix (considered an important biodiversity hotspot for the European territory), its system of open spaces and its structure of public spaces.

> The metropolitan ecological matrix is the result of deliberately overlapping the environmental matrices that are promoted through ecology, the systems of parks defined by landscaping and the structures of civic spaces built under traditional urban planning. It is a system that has to have environmental at the same time as social values and that has to help us build the right relationship between the urban fabric and the open spaces; A strategy to be developed at all scales: from the Metropolitan to each town, from each neighbourhood to each individual. (Area Metropolitana de Barcelona, 2014a, b: 10)

In these proposals, this multi-scale understanding is developed, anchored on three scales and their structuring elements of the ecological network – nodes and accesses, infiltration points, membranes, urban connections, centralities and points of ecological interest. Then, the main physical and ecological connections in the territory are identified. They are characterised as or could produce green corridors (composed of a blue network), which together with the productive landscape regions structure the GI network of Barcelona.

In this context, the urban fringes characterise about 12.8% of the territory. Its fragmented areas and their physical and ecological critical connective points are mapped (listed using symbols to represent the various fragmentations that could occur). Vacant and obsolete land emerges as strategic in promoting ecological areas and in improving the green areas in low-income neighbourhoods in this process.

This Biodiversity potential analysis is complemented by an examination of the condition of the territory's productive landscapes in pastoral areas, agricultural plots and vegetable gardens. The investigation revealed the loss of 75% of productive landscapes from 1956 to 2009. Moreover, the region's loss of biodiversity was also considered, relating to habitats, concentration of biodiversity and agroforestry mosaic.

Following a general mapping of biodiversity, a complementary investigation of the living species – fauna and flora – linked to ecology and biology was conducted. The main species of flora (172 trees, shrubs and climbing plants) and fauna (103 autochthonous vertebrate species, including 72 protected by law, 2 amphibians, 8 reptiles, 55 birds and 7 mammals) were surveyed in these studies. The overlapping of all these readings allowed the definition of 46 points of ecological and physical fragility. Subsequently, a map was drawn with physical and ecological connectivity, articulating soil permeability and the lack of connectivity and the points where this lack is critical. In order to think of a GI strategy that would not approach ecological values (naturalness, diversity, complexity and connectivity) in isolation, a second analysis related these values to sociocultural ones (health, beauty, culture, well-being, connectivity and landscape).

The open spaces of Barcelona's metropolis were investigated for this purpose in order to better understand their characteristics and functions. As the information became more detailed, the 20 most important public spaces in the territory were highlighted and analysed according to the following criteria (guided by ecosystem services): environmental education, drainage, peri-urban planning, ecosystem functionality, thermal regulation, carbon retention, improvement of air quality, infiltration and permeability, artistic inspiration, identity and history, reflection and rest, urban landscape, bond with nature, walk, outdoor games, tourist visit, appreciation of private villas and palaces, appreciation of activities, contribution to mental health, physical health benefits, active ageing and allergy and adaptations to the global impacts of climate change.

After that, mobility networks were identified, for example, mapping the purification channels, historical routes and cycling paths. The concentration of green areas was inventoried and mapped, using 'normalised difference vegetation index' (NDVI), which is an index of green areas created using multi-spectral satellite images. Based on this process, a GI network to aid the recovery and expansion of the ecological, environmental, sociocultural and economic services of 52% of the metropolitan area was planned. In this process, metropolitan leisure spaces, neighbourhood parks and marginal and interstitial spaces were also considered.

In the development of the GI strategy for Barcelona, four elements were presented as the physical limits of the city: the natural park of Serra de Collserola (part of the Natura 2000 Network), the Llobregat and Besós rivers and the coast. From this structure, under the heading of 'biodiversity', different membranes (typologies of GI elements) of the territory were identified; among them were areas of environmental interest (biodiversity hotspots) and areas of historical interest, such as Park Güell, Parc de la Ciutadella, Park of the Labyrinth of Horta, the Pedralbes Palace, the Turó Park and the Tamarita Gardens, all of which are included in the Barcelona City Hall Architectural Heritage Catalogue (a total of 27) (Ajuntament de Barcelona, 2013:18). Areas of interest for afforestation and vegetation under construction, i.e., green walls, balconies, terraces and roof gardens, and associated fauna were also identified (Ajuntament de Barcelona, 2013: 18).

Afterwards, the strategic axes of GI connecting these elements were defined. These take the form of green corridors that perform multiple functions, ordering the metropolitan landscape of Barcelona at the eye level of pedestrians. The areas labelled as green 'infiltrating points', which comprise this corridor, are areas that require renaturalisation, anchored in the aforementioned discussion of NBS, with sociocultural dimensions.

On a regional scale, Barcelona's metropolitan GI network has green corridors, characterised by public and private areas. This network is planned to ensure that a comprehensive need program is fulfilled, considering the target audience and areas of action within and across the metropolitan area. It promotes accessibility and sustainable mobility, as well as the green economy in public spaces. The corridor that integrates the Collserola park area with that of the Monjtuïc park and the Ciutadella park, for example, operates at different scales and embodies multifunctional designs of public spaces from the most naturalised to the most geometrised, exploring multisensory solutions based on nature, expected to boost biophilic relationships.

Planning the GI Landscape Within the Definition of the City of Barcelona's Urban Design: An Example of Transit Between Scales.

Within the corridor linking Collserola park (one of the main structuring elements of Barcelona's GI network) with Monjtuïc and Ciutadella, one of the proposed projects is the green island of Jardíns del Doctor Pla I Armengol, which was developed as the result of mobilisation in the local population. The garden houses the Instituto Ravetllat-Pla, which exhibits Ramón Pla i Armengol's collection of furniture and objects. The garden interacts with its surroundings, functioning as an articulating node for Mar de Monte Serrat Avenue, Cartagena Street, Les Aigües Park and the gardens of Guinardó, through greened paths and routes. The plant physiognomies create different vertical and horizontal visual perspectives due to the background formed by their different shapes, heights, textures and colours. Immersed in this landscape, the passerby is invited to enter the 'green island' that appears at the vanishing point at the end of the route.

The proposal for urban design and landscape intervention in the area is based on a layered reading that seeks to value not only the area's physical attributes but also its sociocultural values, with a focus on heritage. The project aims to interact with the terrain's morphology by including various levels that introduce natural solutions, such as sustainable drainage systems (SuDS), green beds and filter gardens. These levels are interconnected by paths that invite users to experience culture and nature while learning about various plant groups, both with and without water.

In this way, in this process of renaturalisation of the metropolitan region of Barcelona, the value of public spaces is reinforced, according to López, 2014:16: 'Thus, it is recognized that the design of public spaces and the road must guarantee the functionality of the GI and the maintenance of the views and perspectives that characterise it'.

12.4 Conclusion

In the Spanish case, autonomous communities are more independent of central government, and the concept of landscape is more developed, having an identified localised meaning. This is a consequence not only of a more consolidated practice of urban design but also of a greater openness in management bodies. With the deepening and dissemination of the debate on the Spanish methodological strategies of planning and design with GI, there is an evolution of the perspective, from a practice focused on environmental conservation to the understanding of GI as a tool that acts in the planning of the territory at different scales. This tool aimed to promote renaturation and connectivity, through green corridors at the regional scale and greening 'opportunity areas', mostly unoccupied, of different types and sizes at the local scale.

Associated with these actions are the expansion of biodiversity and gains of various kinds, for example, in the quality of art, ecology, agricultural productivity and leisure in the proposed landscape experiences, planned from the development of public policies to their spatial translation into urban design. This multi-scale proposal introduces a new paradigm to the metropolitan approach, concomitantly incorporating ecological and sociocultural dimensions in its decision-making about the future of the region, as well as seeking to understand GI as the fundamental urban infrastructure for landscape planning of the territory along with the plans for mobility and housing, among others. There is a positive effort to respond to contemporary needs, for example, investigating methodological paths that explore the construction of green urban infrastructures supporting a dialogue the grey/built infrastructure, thus making *hybrid infrastructures* that are resilient in the face of climate change at different scales.

Concerning the strategy for the Barcelona region, this proposes greater articulation between the urban and rural areas, reviewing the reduction of foodscapes in the territory and the understanding of rural areas as places for food production and no longer in contact with nature. The renaturalisation process values agrarian areas of high ecological value as well as historical, leisure and artistic significance.

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