Introduction
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This Handbook is about green infrastructure; more specifically, how to plan, design and implement green infrastructure in urban settings. The starting point of the Handbook is that green infrastructure is widely recognised as a valuable resource in our towns and cities. This is because it has the potential to mitigate many of the challenges facing urban environments, including biodiversity loss, environmental degradation and health inequalities. It also has a central role to play in adapting to the future pressures of climate change and food security. An understanding of how to create, protect and manage this resource is therefore crucial.

Green infrastructure is an inherently interdisciplinary and transdisciplinary endeavour that encompasses planners, landscape architects, urban designers, arboriculturists and ecologists from a range of sectors including policy-making, central and local government, charities, community groups and academia. Aimed at all those seeking to achieve sustainable green infrastructure in urban environments, this Handbook provides a core text on how we plan, design, deliver and manage this important resource at different spatial scales.

This Handbook sets the context for green infrastructure as a means to make urban environments more resilient, sustainable, liveable and equitable. It then provides a comprehensive and authoritative account of how to plan, design and implement green infrastructure to achieve these outcomes. The intended audience is researchers and postgraduate students, as well as those outside academia in policy and practice.

The Handbook has five major themed parts, finishing with a final chapter looking at the future of green infrastructure:

- **Part I  The role of green infrastructure in the urban environment.** This examines the role of green infrastructure in improving the health and well-being of urban populations, mitigating the impacts of poor air quality, ensuring our resilience in the face of future climates and providing space for nature in our cities. It is increasingly important to provide a financial value of such ecosystem services and methods for valuing green infrastructure are also provided here.

- **Part II  Strategic planning for green infrastructure.** This concentrates on how green infrastructure can be strategically planned at the national, regional, local and neighbourhood levels, incorporating the development of policies, strategies and plans to ensure green infrastructure is multifunctional and equitable at different spatial scales.

- **Part III  Designing green infrastructure for all.** This part focuses on the detailed design of green infrastructure from an urban design perspective. It sets out the different typologies of green infrastructure, including their objectives and potential outcomes, and then discusses how green infrastructure can be designed to ensure that it is multifunctional and inclusive.
Part IV Implementation and management of green infrastructure. This looks at the practical considerations for delivering green infrastructure, including the role of residential development, combining green infrastructure with land regeneration agendas, management and governance models, and the role of communities in green infrastructure initiatives. It then considers how green infrastructure can be monitored and evaluated using an ecosystem service approach.

Part V Looking forward. Finally, with just one chapter this part attempts to look beyond the present at the role of green infrastructure as a key component of cities of the future.

PART I: THE ROLE OF GREEN INFRASTRUCTURE IN THE URBAN ENVIRONMENT

This part begins with a chapter by Silveirinha de Oliveira and Ward Thompson focused on the relationship between green infrastructure and health and well-being. They begin with an overview of the history of green infrastructure with its origins in the public health and quality of life for urban populations in North America, through the work of Olmsted and Vaux, and Europe, through Howard’s Garden City movement. These early realisations that a network of connected green spaces is critical to counteracting the negative impacts of city living is brought up to date through a summary of the current evidence for the beneficial impact of green infrastructure on physical and mental health. This is followed by a discussion of the implications for planning and design of green infrastructure for health outcomes with a case study, The Greenlink, Scotland, provided as an example of how green infrastructure can improve health and well-being for local residents.

Building on the linkage between green infrastructure and health, Tallis, Amorim, Calfapietra, Freer-Smith, Grimmond, Kotthaus, Lemes de Oliveira, Miranda and Toscano provide further detail on the role of green infrastructure in mitigating poor air quality and elevated air temperatures in cities. The chapter begins by highlighting the significant problems with urban air quality and how this impacts on human health. It then considers three aspects of this – particulate matter, carbon dioxide and air temperature – and examines the impact green infrastructure can have on these through a review of the literature. The section on carbon dioxide capture includes a case study in Florence, Italy. Throughout the chapter the design factors that may be considered to maximise these benefits are presented in order to provide green infrastructure that contributes both to climate change mitigation and adaptation.

In addition to the impact of green infrastructure on air quality and temperature it is also increasingly being used in urban water management. In Chapter 3 Everett, Lawson and Lamond provide an account of blue-green infrastructure that has received a great deal of attention recently for its ability to manage flooding during and immediately after rainfall events. It begins with a summary of the challenges to water management in urban areas, particularly in the context of increased flooding and drought conditions. This leads to a discussion of the paradigm shift currently taking place in urban water management research and policy as we move towards the use of Sustainable Urban Drainage Systems (SUDS) or Water Sensitive Urban Design. This is followed by a consideration...
of the progress to date, the barriers to this and the stakeholders involved in urban water management. Finally, the specific features of green infrastructure that can be included in a SUDS are provided along with an example of a SUDS ‘treatment train’ in Stroud, UK.

The first three chapters provide examples of the ecosystem services provided by green infrastructure. In the fourth chapter, Sunderland, Rolls and Butterworth take a step back from this detail and look at the concept of ecosystems services and its use in the valuation of green infrastructure. They first present the background to ecosystem services and the use of cost–benefit analysis (CBA) and other valuation techniques in green infrastructure decision-making including the most suitable factors that should be considered in a given situation. The urban trees in Torbay, UK, are used as an example to illustrate the process of conducting a CBA. Finally, some guidance for those wishing to conduct or commission an economic valuation of their green infrastructure (or other environmental) project is provided, followed by some limitations of such an approach in the context of sustainable development and the need for a systems approach in the delivery of green infrastructure.

The final chapter in this part examines the role of green infrastructure in biodiversity protection and enhancement. Sinnett presents the argument that nature conservation and green infrastructure are intrinsically linked; the latter can be used to increase biodiversity in cities but the ecosystem services provided by it are largely dependent on the provision of well-functioning ecosystems and, therefore, biodiversity. This chapter summarises the current knowledge on the impact of urbanisation on biodiversity concentrating on the characteristics of green infrastructure that are associated with greater species abundance and richness. This is followed by a consideration of how green infrastructure could be positively planned, designed and managed to enhance biodiversity. Finally, a summary of the challenges and opportunities for green infrastructure to provide space for nature conservation in cities is provided.

PART II: STRATEGIC PLANNING FOR GREEN INFRASTRUCTURE

Part II begins with Mell who explains that while green infrastructure continues to evolve as a concept, its principles have been increasingly developed and applied through policy. By focusing on the past 15 years, and by drawing evidence from the UK, Europe, the USA and Asia, the chapter explains how green infrastructure has permeated into policy at all spatial scales. While green infrastructure is often considered fairly narrowly at the international and national scales, Mell notes that its definition becomes significantly broader at the sub-national and local scales in order to reflect local characteristics and place-specific goals. He also refers to the larger number of actors and ‘advocacy agents’ who tend to operate at this local scale, either through invitation or from their wish to become involved. Mell provides a three-stage model to show how the literature on green infrastructure has shifted, which offers some useful context to the other chapters included in Part II.

Chapter 7, by Gill, Nolan, Butlin, Ferguson and Olver, develops a discussion about the role of sub-national policy by referring to green infrastructure planning across the north-west of England. The chapter focuses on the work of The Mersey Forest, a
community forest that was established in 1991. Over time, green infrastructure has developed into an important framework around which a range of organisations have become mobilised, thereby helping to present a universal case for investment and decision-making across a landscape that continues to bear the scars of industrialisation and its subsequent decline. The Mersey Forest, with a dedicated team at its core, successfully works as a partnership with seven local authorities collaborating with national agencies such as Natural England, the Forestry Commission and the Environment Agency. The chapter traces the involvement of The Mersey Forest in the promotion of green infrastructure, from helping to develop an evidence base to influencing the preparation of plans and strategies across the area.

Throughout Chapter 8 Smith builds on the role that the local context can play in the making and shaping of green infrastructure policy by referring to activity in Cambridge (UK) and Cambridge in the USA (in the state of Massachusetts). Consideration is given to how green infrastructure is framed in policy terms, an overview that builds upon the earlier discussion presented by Mell. The chapter outlines the principal drivers for influencing policy development at each location, such as the need to incorporate green infrastructure in a dense urban area (Cambridge, Massachusetts), or using green infrastructure to help assimilate and integrate major new development (Cambridge, UK). The chapter explores how the planning systems of each city have enabled green infrastructure to be protected and enhanced, with examples being given of how improvements have been secured through the implementation of major development.

The next chapter by Gonçalves and Silva reasserts the importance of integrating landscape and land-use planning together and offers further support to the need for gathering a detailed and sufficiently robust evidence base. The authors highlight the significant role that the European Landscape Convention (ELC) can play in this process, with the convention stipulating how all land should be characterised and assessed with specific landscape quality objectives being developed in response. A case study focused upon the Portuguese village of Óbidos is used to illustrate the type of process that the ELC advocates, with the authors highlighting the need for initial layers of information to be recorded. These layers include the mapping of biophysical characteristics and the subsequent recording of landscape units arising from this analysis. These layers are then combined with maps arising from the identification of goals and objectives from the application of strategic environmental assessment as well as the strategic planning and development goals for the area.

The need to understand the complexities of a landscape is pursued by Quintas in Chapter 10 who argues that green infrastructure planning can only be effective if the multifunctionality of different landscape resources is properly recorded. The chapter presents a methodology for the strategic planning of green infrastructure that comprises a series of steps. Activity is said to be necessary at two scales, namely, in the recording of Strategic Urban Green Infrastructure (SUGI) and Operative Urban Green Infrastructure (OUGI). Importantly, in mapping both, Quintas identifies the need for green infrastructure to be planned beyond the urban landscape to help develop and ensure a positive relationship with adjoining rural areas. In planning for OUGI, Quintas identifies the need for policy-makers and designers to follow certain principles including ensuring that resources are of a sufficient quantity and quality, continuity is promoted and links are made with the wider landscape. The Portuguese city of Porto is used to provide some illustration.
In the final chapter of Part II, Greed reminds policy-makers of the human dimension and explains that strategic plans for green infrastructure must have regard to the diversity in which different members of society choose, or are able to use, green space. By taking such an approach, Greed feels that green space can become an important part of the city’s social infrastructure. She explains how decisions concerning the siting and design of new or protected green space can have implications regarding its potential use. Equally, the way in which a resource is managed or the type of facilities provided alongside it can also have a significant influence on use. A key argument of the chapter is that policymakers and designers should not ‘treat everyone as the same’, instead spatial policy and design responses should be developed that can accommodate a wide range of people.

PART III: DESIGNING GREEN INFRASTRUCTURE FOR ALL

The third part of the Handbook examines the design of green infrastructure as a part of the overall design of the built environment. This begins, in Chapter 12, with an explanation of the typology of green infrastructure, based on land use and function. Here, Burgess sets out the different types of green infrastructure, including the spatial scale at which they generally occur. The functions of green infrastructure are then considered, and categorised into social and cultural functions, ecological functions and economic functions in order to illustrate the multifunctional nature of each type.

In addition to the different functions of green infrastructure, it is also essential to consider that the requirements of users of these functions, and therefore the benefits of green infrastructure, may not be realised. In Chapter 13, Manley looks at inclusive design in the context of green infrastructure and how it sits within the urban fabric, building on the strategic level considerations presented in Chapter 11. The chapter starts with a review of the progress to date towards inclusive design, particularly with reference to disabled and older people, how this could be improved and the benefits of doing so. Finally, a checklist is provided for those wishing to audit green infrastructure, and other components of the built form, for their accessibility to different groups, as well as guidance for those involved in green infrastructure provision be it education, policy or long-term management.

This emphasises the role of the wider built environment in the accessibility and use of green infrastructure. Sinnett, Williams, Lindsay and Dair take this forward in Chapter 14 with the results of a study investigating how neighbourhood design affects the use of public open spaces in 13 sustainable developments in the UK. Based on a survey of the neighbourhoods and a household questionnaire, the results point to several characteristics of the neighbourhood design that are associated with greater use of public open space. These features are often those commonly associated with good-quality walking environments and this highlights the importance of urban context in which green infrastructure, as a local amenity, is located if it is going to be used.

Part III now turns to the individual site level, specifically looking at designing green spaces and school grounds in parallel, as a shared resource for both children and older people. Rigolon, Derr and Chawla examine this through a case study in Boulder, Colorado (USA). First, a summary of the literature is presented to identify the features of green spaces that have been reported to be important for the two user groups. They then take the reader through a participatory design process that sought to engage school
children and older people in the case study neighbourhood in the design of a local greenspace that was to be combined with the school grounds. Some lessons learnt are then presented for those wishing to adopt a similar approach, although the importance of designing for a specific place, its community and their needs is highlighted.

In Chapter 16, Short examines the role of green infrastructure in the historic urban environment. The chapter begins with a discussion of the historic environment, how it relates to the character of place and how the green infrastructure is intrinsically linked to this. It uses the example of Vancouver (Canada) to illustrate how green infrastructure is fundamental to the character of the city and how conservation planning has been instrumental in ensuring its success. In contrast to the previous chapters, Short highlights the role of green infrastructure outside the city, but visible from within it, in contributing to the sense of place and how this can be protected by allowing good-quality, high-density development mediated by green infrastructure.

In the final chapter in Part III Marques-da-Cruz and Costa Pinto discuss the role of green infrastructure in the landscape, developed over time from a combination of biophysical processes and cultural interpretation. It then raises concerns regarding the sustainability of cities if landscape and natural features are lost during the process of urbanisation. The fundamental role of green infrastructure in preserving the natural components of cities while allowing development is then illustrated through two case study green spaces, one in Portugal and another in Italy. These coastal examples demonstrate the importance of green infrastructure in reconciling natural settings and processes with those of intense urbanisation in a flexible way that is able to adapt to future needs.

PART IV: IMPLEMENTATION AND MANAGEMENT OF GREEN INFRASTRUCTURE

In this part of the Handbook, we turn to the delivery of green infrastructure. In Chapter 18 Collomb discusses the pros and cons of the various governance models operating in green spaces from state centred to user centred and the different scales at which this happens. This is followed by a consideration of the skills required to manage green infrastructure, the approaches to management and the different funding mechanisms that are in operation. The chapter particularly highlights the importance of partnership working in delivering successful green infrastructure and uses a range of international examples to reinforce the arguments being made. It also provides an analysis of the future trends in green infrastructure governance and funding with some suggestions as to the direction of travel.

Building on one aspect of this, Chapter 19 looks at community involvement in green infrastructure. In this Coombs examines how community involvement has emerged as a significant component in the delivery of green infrastructure and discusses the benefits that this brings to projects and programmes. This is followed by an overview of the different forms community involvement can take, depending on the nature of the project and how it is embedded in policies and legislation in the UK and Europe and the various contexts in which it occurs. As with the preceding chapter a series of examples are used to illustrate the points raised. The chapter concludes with some key recommendations for successful community involvement in green infrastructure projects.
In the next chapter Payne and Barker examine residential development as a vehicle through which green infrastructure can be delivered. At the outset they argue that green infrastructure has emerged as an intrinsic component of sustainable development and economic growth in the UK. They discuss the speculative house-building sector in the UK, particularly with reference to its business model and ability and willingness to engage with the sustainable development agenda and how this relates to green infrastructure provision. An empirical study is then presented that investigates the attitudes and perceptions of large house-builders towards the delivery of green infrastructure in residential developments. Using the results of a questionnaire, they discuss the motivations and barriers to the sector in providing green infrastructure and discuss what this may mean in the context of the UK.

In addition to housing development, the establishment of green infrastructure is often a key component of the regeneration process. In Chapter 21 Moffat discusses the role of green infrastructure in urban regeneration, particularly with reference to brownfield land. First he identifies the key economic, environmental and social benefits of green infrastructure in this context, followed by an exploration of the technical challenges that exist, including competencies, soil conditions and balancing the needs of wildlife. He then goes on to detail the process of regeneration including guidance on site investigation, soil placement and cultivation, and species selection. Finally, a discussion of the main challenges to the success of green infrastructure delivery on brownfield sites is presented.

The final chapter in Part IV, by Doick and Wilson, looks at monitoring and evaluation of green infrastructure projects. First, they outline the imperative for monitoring and evaluation in the successful implementation of green infrastructure. They then detail the use of logic modelling, in conjunction with an ecosystem services approach, as a way of conceptualising the different services that may be provided by green infrastructure to aid the development of a monitoring and evaluation strategy. Building on the previous chapter, an example project of the regeneration of a brownfield site, a landfill, to community woodland is used to demonstrate the use of logic modelling. Seven worked examples are provided to illustrate the different ecosystem services that may be provided by the woodland and logic modelling used to identify the key inputs, processes, outputs and outcomes as a way of structuring the monitoring and evaluation.

PART V: LOOKING FORWARD

The rest of this book has looked very much at the current state of green infrastructure, in terms of its benefits to counteract the negative consequences of urbanisation and how this may be most effectively achieved. In the sole chapter in this part Moffat, Sinnett, Smith and Burgess attempt to identify the key trends happening in our cities and the role green infrastructure may play in shaping their development, and how it may, in turn, be shaped by them and the expectations of their citizens. The chapter highlights how if green infrastructure is to aid our resilience to future conditions, it will itself need to be able to withstand these pressures. Finally, it provides some insight into how this may be achieved in the future.