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Synthesis report summarising the comparative analysis of UFBS implementation

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Summary

To address the complexity and multidimensionality of UF-NBS and to make the best of the multiple geographic, thematic, and disciplinary expertise present in the consortium, we realised what could be called an "articles-based report". This is an approach to the research where we tackle the research question by looking at its multiple dimensions through a number of articles and reports. Deliverable 2.2, thus, is a combination of a synthesis report (the present document) and a clip of 13 research articles. This document brings together all the findings and formulates lessons learnt from a Sino-European perspective, within a coherent and comprehensive picture. It summarises the articles focusing on the elements that are critical to realise the comparative in-depth analysis and illustrates the thread that connects all of them. It includes both original texts, as well as portions of the articles that are referred to. In the interest of clarity, this cumulative document also re-proposes some key elements of other tasks and deliverables (e.g. in relation to the context, to the methods, and to key findings). The individual articles can be read either as chapters of this report (i.e. after each and every individual sub-chapter), or separately. All of them can be read as independent pieces of research. They describe their respective objectives and research questions, refer to the relevant bibliograph, illustrate the methodology, the empirical material, and the findings (see Appendix 3 for a complete list of articles followed by the full versions).

Approval

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Table of Contents

List of Tables **2**

List of Figures **3**

EXECUTIVE SUMMARY **4**

KEYWORDS **4**

ABBREVIATIONS **4**

KEY DEFINITIONS **4**

VERSION HISTORY **6**

REFERENCE **6**

1 INTRODUCTION **7**

1.1 The context: UF-NBS and the CLEARING HOUSE project 7

1.2 Work package 2 - Conducting a comparative analysis of case study-cities 7

1.3 An articles-based report building on multiple disciplinary and professional expertise. 8

1.4 Overview of the structure 13

2 GOVERNANCE AND MANAGEMENT **14**

2.1 Governance models for NBS: seventeen cases from Germany [comparative paper]. 18

2.2 Co-production of urban forests as nature-based solutions: motivations and lessons-learnt from public officials [comparative paper] 21

2.4 Citizen science and UF-NBS [comparative reports] 27

3 THE GEOGRAPHY OF UF-NBS: EXPLORING QUESTIONS OF CONNECTIVITY AND ACCESSIBILITY **31**

3.1 Accessing the functional connectivity of urban tree systems [comparative report] 32

3.2 The role of Brownfields and Their Revitalization for the Functional Connectivity of the Urban Tree System in a Regrowing City [Single City Paper] 33

3.3 Conceptualising multidimensional barriers: a framework for assessing constraints in realising recreational benefits of urban green spaces [conceptual paper] 35

3.4 Taking one step further: Advancing the measurement of green and blue area accessibility using spatial network analysis [single city paper] 36

3.5 Permeability of the city–Physical barriers of and in urban green spaces in the city of Halle, Germany [single-city paper] 37

3.6 Planning to Practice: impacts of large-scale and rapid urban afforestation on greenspace patterns in the Beijing Plain Area [Single-City Paper] 38

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4 THE CITY AND TREES: HOW SOCIAL AND ECOLOGICAL DYNAMICS MIRROR EACH OTHER IN THE URBAN SPACE 38

4.1 What are the traits of a social-ecological system: Towards a framework in support of urban sustainability. [Conceptual paper] 39

4.2 Higher immigration and lower land take rates are driving a new densification wave in European cities [comparative paper] 41

4.3 Between green spaces and mobility: exploring diverging perspectives on the admission of motorised traffic in the Bois de la Cambre (Brussels, Belgium) [single city paper] 43

4.4 The park street: striking the balance between mobility, biodiversity, and permanence functions of public space (Brussels, Belgium) [single-city paper] 45

5 CONCLUSION 47

5.1 Key Findings - Governance and Management of UF-NBS (Chapter 2) 47

5.1.1 Governance and Management: Key Recommendations 48

5.2 Key Findings – The Geography of UF-NBS: exploring questions of connectivity and accessibility (Chapter 3) 49

5.2.1 The Geography of UF-NBS: Key Recommendations 49

5.3 Key Findings – The City and Trees: how social and ecological dynamics mirror each other in urban space (Chapter 4) 50

5.3.1 The City and Trees: Key Recommendations 51

5.4 Key Findings – Comparing UF-NBS in Europe and China 51

BIBLIOGRAPHY 54

APPENDICES 57

Appendix 1: Justification for the selection of deliverables and milestones used in this report (D2.2) 57

Appendix 2: Justification for the selection of publications/reports used in this report (D2.2) 58

Appendix 3: Full versions of the articles (in chapter/section order) 60

List of Tables

Table 1.1 European and chinese case study city characteristics and UF-NBS challenges (T1.5, Scheuer et al., 2020) 11

Table 2.1 Urban planning governance landscape for the 10 CLEARING HOUSE case study cities in Europe and China (adapted from: Roitsch et al. 2021; Haase et al. 2021) 14

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 821242 and the National Key R&D Programme of China under grant No 2021YEF0193200. The content of this deliverable does not reflect the official opinion of the European Union. Responsibility for the information and views expressed lies entirely with the author(s).

Table 2.2 UF-NBS governance, planning and citizen participation in the European case study cities (Haase et al. 2021) 14
Table 2.3 UF-NBS governance, planning and citizen participation in four Chinese case study cities (Haase et al. 2021) 16
Table 2.4 Synthesis of the main results of the governance model typology 18
Table 2.5 Analysis of co-produced UF-NBS projects in four European cities 22
Table 2.6 Comparative identification of knowledge gaps related UF-NBS in the EU city case studies. 28
Table 2.7 Comparative analysis of the barriers to citizen science related to UF-NBS in the EU city case studies 29
Table 3.1 Profile of characteristics for connectivity of urban tree systems in five case study cities 28
Table 5. 1 Comparison of UF-NBS in Europe and China 45

List of Figures

Figure 1.1 Process diagram for producing D2.2 (Work Package 2, Task 2.2) 9
Figure 2.1 Share of UF-NBS municipality budget (Source: Biaz, L., 2022, T2.2) 26

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EXECUTIVE SUMMARY

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Deliverable 2.2, thus, is a combination of a synthesis report (the present document) and a clip of 13 research articles.

This document brings together all the findings and formulates lessons learnt from a Sino-European perspective, within a coherent and comprehensive picture. It summarises the articles focusing on the elements that are critical to realise the comparative in-depth analysis and illustrates the thread that connects all of them. It includes both original texts, as well as portions of the articles that are referred to. In the interest of clarity, this cumulative document also re-proposes some key elements of other tasks and deliverables (e.g. in relation to the context, to the methods, and to key findings).

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KEYWORDS

Urban forests, nature-based solutions, governance, management, connectivity, accessibility

ABBREVIATIONS

UF-NBS: Urban forests as nature-based solutions

NbS: Nature-based solutions

CS: Citizen science

CES: Cultural ecosystem services

EES: Ecological ecosystem services

UGS: Urban green space

KEY DEFINITIONS

Urban forests: tree-based urban ecosystems that address societal challenges, simultaneously providing ecosystem services for human well-being and biodiversity benefits. Urban forests include

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peri-urban and urban forests, forested parks, small woods in urban areas, and trees in public and private spaces.

Urban forestry: the practice of planning and management of urban forests to ensure their health, longevity and ability to provide ecosystem services now and in the future.

Nature-based Solutions (NbS): Nature-based Solutions (NbS) are defined as *"actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits"*. (IUCN, 2018)

Urban forests as nature-based solutions: UF-NBS are a subset of nature-based solutions, that build on tree-based urban ecosystems to address societal challenges, simultaneously providing ecosystem services for human well-being and biodiversity benefits. UF-NBS include peri-urban and urban forests, forested parks, small woods in urban areas, and trees in public and private spaces. UF-NBS comprise every measure a city can take to address urban development challenges by deploying tree-based ecosystems. (European Forest Institute, 2018)

Urban tree(s): usually long living woody organism including woody shrubs, usually single stemmed, with the potential to grow at a site in a urban or peri-urban area. This includes roadside trees, trees in squares, parking areas, or in parks and private gardens. Urban trees appear as individual trees, or as groups of trees.

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VERSION HISTORY

Version	Date	Author	Partner	Description
V1	20 Sep 2023	Armstrong, A.	VUB	First draft circulated to VUB co-author
V2	6 Oct 2023	Armstrong, A., da Schio, N.	VUB	Co-author edited chapter 4; revised structure based on VUB co-author discussions. Circulated version to all co-authors
V3	26 Oct 2023	Armstrong, A.	VUB	Incorporated feedback from co-authors.
Final	28 Oct 2023	Armstrong, A.	VUB	Submitted to Rik De Vreese and Clive Davies
Final Template	20 Nov 2023	Armstrong, A.	VUB	Incorporated feedback. Entered report into the CLEARING HOUSE template for deliverables and included full versions of the articles in the Appendix.

REFERENCE

Armstrong, A., da Schio, N., Baró, F., De Vreese, R., Wolff, M., Krajter Ostoić, S., Mishra, H., Tyrväinen, L., Forgeois, F., Suarez Groen, H., Nesselhauf, G. and de Bellis, Y. (2023) *A comparative analysis of UF-NBS implementation: synthesis report* (D2.1). H2020 project CLEARING HOUSE, agreement no. 821242.

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1 INTRODUCTION

1.1 The context: UF-NBS and the CLEARING HOUSE project

Trees and forests are a proven nature-based solution that contribute to sustainable urban development. Their potential for delivering ecosystem services, enhancing biodiversity and contributing to the well-being of urban societies is often underestimated and underused. In this context, the concept of **urban forests as nature-based solutions** (UF-NBS) has come to the fore recently. UF-NBS encapsulates a wide array of measures that cities can implement to tackle the multifaceted challenges of urban development, all centred around the strategic deployment of tree-based ecosystems. This encompasses everything from revitalizing degraded urban environments and re-establishing vital connections within cityscapes to the restoration of tree-based urban ecosystems, ensuring they thrive and flourish. By recognizing and capitalizing on the transformative power of UF-NBS, cities can take significant strides towards creating more resilient, sustainable, and harmonious urban habitats.

In the context of the broader research and policy agenda on UF-NBS, the CLEARING HOUSE project ("Collaborative Learning in Research, Information-sharing and Governance on how urban forest-based solutions support Sino-European urban future"), has been a 54 month research project (2019-2023) funded through the European Union's Horizon 2020 (H2020) research and innovation programme. The primary objective of the project was to provide compelling evidence and a suite of practical tools designed to facilitate the harnessing of the full potential of UF-NBS. To do so, CLEARING HOUSE has brought together cities and research institutions from both Europe and China to design and develop an articulated framework of research and actions to realise urban development patterns that are both more resilient but also offer enhanced quality of life. Inter alia, CLEARING HOUSE explores pathways for the cost-effective restoration of degraded urban and peri-urban environments and the enhancement of ecological connectivity; as well as actionable solutions to improve human wellbeing and social inclusion and create better conditions for biodiversity and the delivery of ecosystem services such as clean air, microclimates, and aesthetics.

1.2 Work package 2 - Conducting a comparative analysis of case study-cities

Work package 2 (WP2) is one of six work packages in the CLEARING HOUSE project [Months: 5-50]. Its main objective was to analyse and compare the implementation of UF-NBS in selected cities and city regions, focusing -among other things- on their impacts on urban ecosystems and societies, their cost-effectiveness, and their replicability in distinct contents. WP 2 drew on the analytical framework developed under Task 1.5. It involved most CLEARING HOUSE partners, including research partners responsible for gathering data and conducting scientific analysis and city partners.

WP2 was a two-steps endeavour, including first an exploratory analysis of all selected case study cities (Task 2.1); and secondly in-depth comparative analysis of multiple dimensions of UF-NBS at the level of case study cities and city regions (Task 2.2; main deliverable: Deliverable 2.2).

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The results of the exploratory analysis of case-study cities (Task 2.1) were illustrated in a report (Deliverable 2.1, da Schio et al., 2023), the key elements of which are summarized below for easy reference.

- Part I of the report made the case for and performed a two-level comparative analysis, showing and reflecting on the trade-off between maps content and spatial coverage. Using the most recent available and comparable data provided by the Copernicus program, we conducted a first cartographic assessment the UF-NBS potential in European urban areas. The analysis of forest areas availability (i.e., forest share), the potential per-capita supply with forest areas, and the use intensity (forest area per resident), as well as the biophysical benchmark of canopy cover (tree cover density) have made emerge the huge variety of city performance in Europe, and positioned the CLEARING HOUSE localities in the European landscape. Analysing the relation between certain indicators allowed a preliminary but illustrative conclusion on the influencing factors such as built-up structure or city size.
- Part II was based on a qualitative and in-depth methodological approach, which allowed to draw a detailed picture of the nine CLEARING HOUSE localities in general terms, as well as in relation to UF-NBS dynamics.
- Despite their diverse geographical, socio-economic, environmental, or institutional contexts, all case study cities were found to be shaped by a long history of human management which has resulted in complex (urban) social-ecological systems. The concepts of silvan city (in the Sonian city) or industrial nature (in Gelsenkirchen) are clear examples of the strong links between social and ecological (also technological) aspects in these areas. Because of its embedding in highly urbanised and dynamic environments, all of the analysed (peri)urban forests (and other types of urban green infrastructure) were found to be subject to different threats. Fragmentation due to transport infrastructure, pressure from urbanisation processes (both densification and urban sprawl), or congestion due to (massive) recreational use are some of the challenges faced by several case study cities. Only Gelsenkirchen (and its larger Ruhr region) reports impacts related to droughts, severe storms and forest diseases and plagues, although other cases are probably also affected by these problems.

Building on the findings of Task 2.1 (da Schio et al., 2023), on the analytical framework developed in T1.5 (Haase et al., 2021) and the results from the local co-design workshops carried out under T3.1, Task 2.2 aimed to make a step forward and delve into an in-depth analysis of multiple dimensions of UF-NBS. The results of Task 2.2 were compiled in the present research report, which is also informed by feedback gathered at a workshop during the CLEARING HOUSE 4th General Assembly in Krakow, Poland.

1.3 An articles-based report building on multiple disciplinary and professional expertise.

Two key features define the form and the nature of Deliverable 2.2. It is a report based on different independent but complementary articles. It is a report realised thanks to the contribution of professionals with different expertise: researchers with different backgrounds, methodological training, and faculty of reference, but practitioners and experts based outside of academia.

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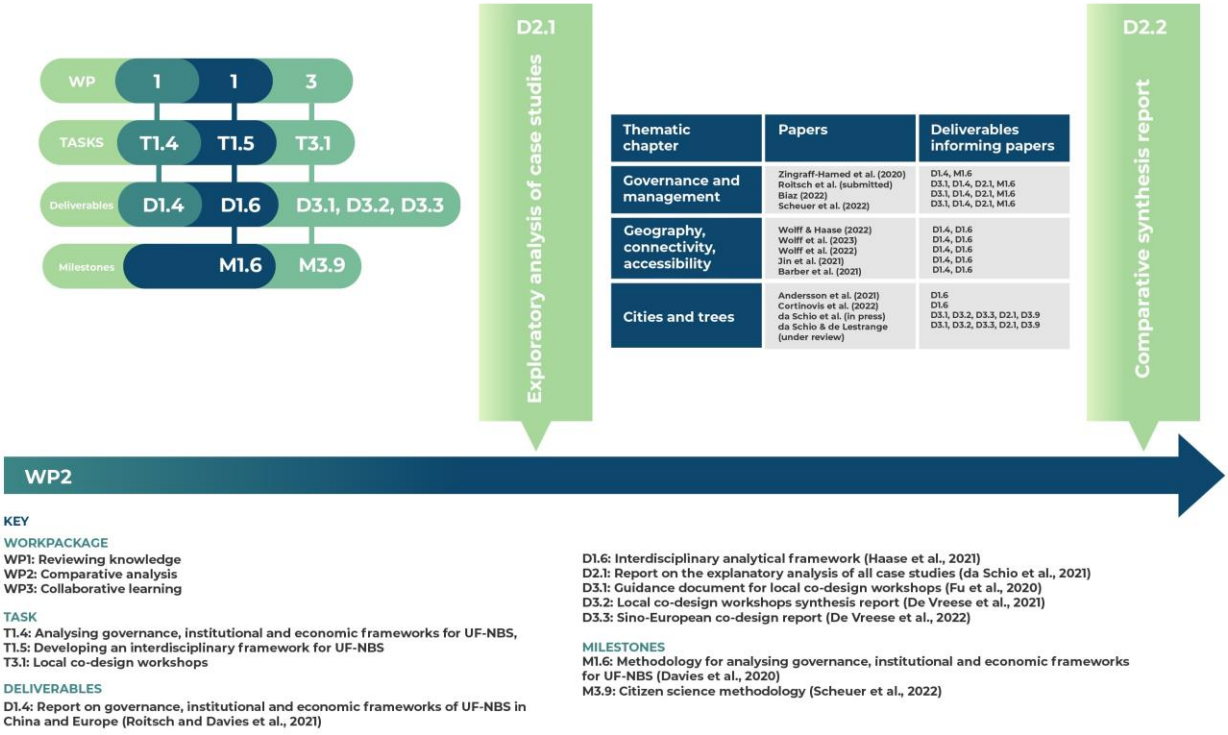
An **articles-based cumulative report**. Building on the lessons learned from the "Exploratory analysis of the CLEARING HOUSE case study cities" (WP2, Task 2.1, da Schio et al., 2023), task partners decided to structure the D2.2 as an "articles-based report", that is: compilation of a number of items such as scientific articles, concept papers, and reports, independent from one another. This is an approach that is increasingly common in academia (e.g., articles- based PhD thesis), allowing to produce at the same time wide-ranging texts addressing the multiple dimensions of an issue, as well as sharp and in-depth building blocks focused on specific research questions and methods. This tactic is effective to deliver both synthesis and in-depth results. In particular, the articles we selected include scientific papers based on the analysis of empirical material (published or submitted) and developing a comparison between multiple cities, participating or not in the CLEARING HOUSE project; single-city scientific articles providing further, more specific examples from single case study; conceptual papers, proposing theory or bibliography based reflections; hands-on reports written by and for practitioners (see Figure 1.1 and Appendix 1 and 2 for selection justification).

Figure 1.1 Process diagram for producing D2.2 (Work Package 2, Task 2.2)



A **multi-expertise report**. Thanks to the wide range of partners within the CLEARING HOUSE consortium, and the different professionality that were brought together on the project, the report could count on a diversity of professionals looking at UF-NBS through different lenses and writing about that in different ways. The style that emerges through the various parts of the report reflects

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this diversity, and while it might lack a certain homogeneity throughout it expresses one of the key strengths of the CLEARING HOUSE team.

This approach was considered to be more effective and more efficient: it would be in line with the dominant form of scientific knowledge production today (i.e. relatively brief articles on specific questions), it would benefit from the diversity of the consortium without being threatened by it, and would be more resilient to the long-term planning-related problems arisen following the COVID-19 disruption and the delayed Chinese funding. This approach, also, allowed a more flexible and adaptive relation with the other work packages and in general to the other activities of CLEARING HOUSE. In that, some of the articles also represents the written output of another WP, or the analytical reflection about a given activity.

One of the limits of the approach we followed is that the comparative angle is probably underdeveloped vis-à-vis the ambitions of the project proposal and of the plans developed in the early stages of the CLEARING HOUSE project. The initial idea was to conduct a comparative analysis of 10 paired cities and city region in Europe and China, that is an EU city with certain characteristics with a similar city in China, and this repeated for five pairs. Such an analysis was not possible: the Chinese partners only received their funding very late, and their activities were limited -inter alia- by the sanitary situation (COVID-19) and the consequent frequent lockdowns, limitations to travel and reduced staff capacity. In addition, we experienced limited consistency in the data collected from the core European and Chinese case study cities due to various factors, including issues related to data sharing[1]. At the same time, believing in the importance of a comparative approach to shed light on UF-NBS governance and geography, and to compensate for the missing EU-China comparison, we took a comparative angle in numerous of the articles included in this deliverable, as well as in the conclusion.

Multi-domain report: thematically, the report is structured along three thematic chapters or "research streams": governance and management, geography of UF-NBS – connectivity and accessibility, and the city and trees. Each thematic chapter includes four to five articles (see Appendix 3 for the full articles). This choice was based on the work conducted in Year 1 and Year 2 of CLEARING HOUSE, notably the standardised Sino-European UF-NBS typology (T1.1, Scheuer et al., 2021), the reference-recorded repository of policy-based and scientific knowledge of UF-NBS and their impacts (T 1.2, DeBellis et al., 2020 and T.1.4, Roitsch et al., 2021), the Sino-European co-design event (T3.1, Fu et al., 2020), the exploratory analysis of all case study cities (T2.1, da Schio et al., 2021), and the Analytical Framework for case study research (T1.5, Scheuer et al., 2020). If the research streams were initially four (inter alia, see detailed plan - Milestone 2.4 (da Schio, 2022), and the progress report), once the research was conducted, we opted to reduce this number to three to increase internal consistency and the flow of the text.

The research streams were conducted in parallel, under the leadership of consortium partners. They are complementary and connected to one another, both in terms of the theme they covered (the multiple dimensions of the UF-NBS universe) and in terms of the approach that was taken.

Practically speaking, once the research streams were identified, a survey was circulated to the consortium to call for contributions in one or more research streams, and a detailed plan was

[1] The challenges of conducting a full-fledged Euro-Chinese project were fully disclosed in due time with the funder.

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developed and submitted in April 2022 (M2.4, da Schio, 2022). Afterward the modus operandi was such that the work of every workstream was conducted with a relative degree of autonomy and following a plan decided by the coordinator and by the participants (i.e., specific timing & content realised). Every month all research stream leads (plus observers from the steering committee and other tasks, as needed) have met and exchanged. This approach allowed to make the best of the participants expertise and interest in advancing the research within a given domain and minimise loss of time and resources in coordination.

Geographically, the report focuses on five European case study cities – Leipzig-Halle (Germany), Gelsenkirchen/Ruhr Area (Germany), Barcelona (Spain), Brussels Capital Region (Belgium) and Krakow, (Poland), and five Chinese case study cities – Beijing, Xiamen, Huaibei, Hangzhou and Hong-Kong-Guangzhou-Shenzhen[2]. Table 1.1 summarises the key characteristics of each city and the UF-NBS challenges they face.

Table 1.1 European and Chinese Case Study City Characteristics and UF-NBS Challenges (T1.5, Scheuer et al., 2020)

City/metropolitan region	Country	Population (approx.)	Key Characteristics	UF-NBS Challenges (T1.5, Scheuer et al., 2020)
Leipzig-Halle	Germany	2,400,000	Formerly heavy industry region, today one of the fastest growing city-regions in Germany. Problems of air pollution from traffic.	UF-NBS for river catchment restoration, increasing attractiveness and nature connectivity.
Gelsenkirchen/Ruhr Area	Germany	260,368	Former industrial city/region with heavy industry, stagnant and aging population coupled with high immigration.	UF-NBS for restoring former mining sites and for urban regeneration and sociocultural integration.
Krakow	Poland	760,000	Historical city and industrial district of Nowa Huta, significant share of natural areas, high pollution.	Business model for implementing UF-NBS for air-quality improvement.
Barcelona (Metro area)	Spain	3,240,000	Old compact city with industrial hinterland.	Afforestation and UF-NBS for river catchment restoration and delivery of green infrastructure strategies.

[2] Whilst the main focus is on the five European and four case study cities from China there is mention of other cities in some chapters where the Work Package leaders have included them in their work.

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Brussels Capital Region	Belgium	1,208,542	European capital city, densely populated areas targeting nearby natural sites for the development of a network of recreational areas.	Business model for inner-city afforestation and UF-NBS for enhancing urban-rural territorial linkage.
Beijing	China	21,542,000	Global city with rapid urban expansion and population growth, post-industrial economy.	UF-NBS for various ecosystem services (e.g. air purification, heat-wave mitigation, outdoor recreation).
Xiamen	China	3,531,000	One of the most liveable cities with tourism; one of the first special economic zones open to international trade and investment.	UF-NBS for inner-city afforestation and coastal shelter-belt forest systems.
Huabei	China	2,040,000	Coal-resource-based city with heavy industry, experiencing the transition to hi-tech industry.	UF-NBS for restoring former mining sites and for urban regeneration.
Hong-Kong-Guangzhou-Shenzhen	China	34,915,200	Rapidly urbanising and economically vibrant region in transition from traditional labour-intensive industry to hi-tech.	UF-NBS for river catchment restoration, increasing attractiveness, ecological connectivity and water quality.
Hangzhou	China	9,806,000	Tourism city/national ecological garden city with high forest coverage.	Business model for implementing UF-NBS for air and water quality and attractiveness for tourists.

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1.4 Overview of the structure

The report is organised as follows:

Chapter 2 focuses on the **governance and management of UF-NBS.** There are two key comparative papers used in this chapter. The first explores governance models and draws on 17 case studies in Germany. It is a useful paper, because we use their NBS governance model to add an extra layer of comparative analysis to the UF-NBS case studies in the second comparative paper which examines the perspective of local government staff on co-producing UF-NBS in seven European cities. Two comparative reports complete this chapter. The first focuses on sustainable funding mechanisms for UF-NBS and cost-effectiveness and the second on citizen science methodologies for city case studies.

Chapter 3 considers the **geography of UF-NBS** in cities with a focus on questions of **connectivity and accessibility.** There is one key comparative paper in this chapter providing an in-depth analysis of accessing the functional connectivity of urban tree systems in the five European case study cities. Four single city papers offer insights into: the role of brownfields for the functional connectivity of urban tree systems in Leipzig, Germany; how to measure green and blue area accessibility using spatial network analysis; understanding the permeability of the city through an exploration of physical barriers of and in Urban Green Space (UGS) and finally, the impact of large-scale and rapid afforestation on green space patterns in Beijing, China.

Chapter 4 takes a **multidisciplinary approach to UF-NBS** zooming out and looking at them in the relation to urban phenomena. The basic tenet is that the urban forest does not grow in vacuum: its distribution in space, its growth and cutback, and its governance are tightly embedded in a broader socio-political and infrastructural context. Speaking of UF-NBS, therefore also means to speak about public space, mobility, migration, urbanisation, ... We called this chapter: "***The city and the trees: how social and ecological dynamics mirror each other in the urban space***", precisely to put emphasis on the interdependence between UF-NBS and all the wider city landscape.

In the **conclusion** we consider the key findings of our thematic comparison.

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2 GOVERNANCE AND MANAGEMENT

The governance of UF-NBS represents a dynamic and multifaceted approach to managing the urban environment in a way that maximizes the benefits of trees and green spaces for both people and the planet. As cities continue to expand and grapple with the challenges of climate change, pollution, and population growth, effective governance in this context is paramount.

As a starting point and to understand the context for comparing governance and management in CLEARING HOUSE case study cities, we first remind ourselves of the similarities and differences in UF-NBS governance, planning and citizen participation identified in Deliverable 2.1 (Haase et al. 2021) see Table 2.1, Table 2.2, and Table 2.3).

Table 2.1 Urban Planning Governance Landscape for the 10 CLEARING HOUSE case study cities in Europe and China (Adapted from: Roitsch et al. 2021; Haase et al. 2021)

Planning Family	Key word description	Countries (CLEARING HOUSE countries in bold)	Number of CLEARING HOUSE Case Study cities	CLEARING HOUSE Cities
Central	Regional economic planning	Austria, **Germany**, France, **Belgium**	3	Gelsenkirchen; Leipzig; Brussels
New Member States	Post-socialist	**Poland**, Slovenia, Croatia	1	Krakow
Mediterranean	Urbanist & rigid	Italy and **Spain**	1	Barcelona
Chinese	Centrally derived	China	5	Beijing; Huaibei, Xiamen; Hong-Kong-Guangzhou-Shenzhen; Hangzhou

Table 2.2 UF-NBS Governance, planning and citizen participation in the European case study cities (Haase et al. 2021)

City/ Country	Krakow, Poland	Gelsenkirchen, Germany	Brussels, Belgium	Barcelona, Spain	Leipzig, Germany
Governance	Municipal Green Space Authority (ZZM) in city government	Gelsenkirchen is located in the federal state of North Rhine-Westphalia (NRW) in the middle of the Ruhr	One of the most important policy instruments is	Complex institutional framework, with multiple levels of	German planning system has a central legal framework and a

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	responsible for all green spaces	metropolis (Ruhr area). The Ruhr Regional Association (RVR) - an association of 11 independent big cities and four rural districts - is responsible for regional planning. The RVR is also the organizer of important green infrastructure projects such as the Emscher Landscape parc (ELP; 450 km²) and currently the "Green Charta" for the Ruhr Metropolis.	the "Natura 2000" network	government but lacks a governance model for nature	decentralised decision-making structure. The cities alluvial forests protected by the EU Forest-Fauna-Habitat and Bird Directives (Natura 2000)
Planning	Spatial planning documents for increasing afforestation (2018 – 2040) and developing and managing green areas (2017 – 2030)	Municipal land-use planning is located below regional planning; it covers the area of a municipality in the form of land use planning. Gelsenkirchen had a legally binding "landscape plan" since 2000.	Three separate planning frameworks; administrative fragmentation at the regional, provincial and communal level.	Key planning document at metropolitan level is the metropolitan PDU (*Pla Director Urbanistic Metropolità*; Urban Master Plan; AMB, BR, 2019)	Regional Development Plan (REP) introduced in 2008; regional development concept "Green Ring of Leipzig" has been implemented in the area of the Leipzig urban fringe. Initiated in 1996 by Leipzig planning officials
Citizen participation	Often reduced to limited groups of active inhabitants, projects' meetings and consultations.	Various projects in the city of Gelsenkirchen aim to strengthen citizen participation in the topic of sustainability. This includes "GE greens". Currently, a "green citizens' budget" is to be provided based on data from an urban environmental sensor network, which is intended to support	At different levels new forms of participatory approaches emerging, e.g. citizen science	Metropolitan PDU involved 500 experts and a complex participatory process, with more than 10.500 participants. The 1st planning process at scale using	INSEK Leipzig 2030 is the latest planning concept and had an intensive multidisciplinary, multi-stakeholder process. Public participation was structured by Leipzig Thinking Ahead, the City of

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		the development of tailor-made climate adaptation measures.		participatory processes such as citizen science, participatory mapping, visualization tools, Living Labs	Leipzig's coordination centre for public participation. Citizens involved in the development of the street tree concept Leipzig 2030 within an extensive participation and coordination process.

Table 2.2 shows that there are similarities between the five European cities in that there are **governance structures** to manage green spaces and urban forestry, though the level of governance varies. Each city engages in **planning** efforts related to green spaces and urban forestry, with varying degrees of specificity and all cities emphasize some level of **citizen engagement**, but the extent and methods vary.

As one might expect, there are more differences that similarities when comparing governance of nature in the cities: Krakow is governed by the *local* Municipal Green Space Authority (ZZM); Gelsenkirchen is part of the *regional* Ruhr Regional Association (RVR), indicating a more regional approach to governance involving multiple municipalities; Brussels operates within a *complex institutional framework* with various levels of government, including inter-regional, regional, and local authorities (but with a shared common vision for the Sonian Forest); Barcelona faces a complex institutional framework with *multiple levels of government* but *lacks a specific governance model for nature* and Leipzig operates within the German planning system, characterized by a *central legal framework and decentralized decision-making*, with protection of alluvial forests by EU directives. Each city's approach reflects its specific challenges and opportunities in managing green spaces and promoting UF-NBS.

Table 2.3 UF-NBS Governance, planning and citizen participation in four Chinese case study cities (Haase et al. 2021)

	Beijing	**Xiamen**	**Huabei**	**Hong Kong Guangzhou-Shenzhen**
Governance	Central e.g. National Forest City Development Plan (2018-2025). Sets agenda, key tasks etc.	Central e.g. 18th National Congress to build a beautiful China, including protection of ecological spaces.	Central National Forest City Development Plan (2018 – 2025). Huabei set up departments and institutions related to ecological	Central State Forestry Administration approved in 2016 the Pearl River Delta region as the first 'national forest city cluster construction demonstration zone' in China.

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		Beautiful Xiamen Strategic Plan; Xiamen Ecological Functioning Zone carries out regional conservation and management	construction e.g. Municipal Forest Bureau	Central directives issued on scientific greening, realisation of ecological products, implementing a forest system, forest city cluster construction, national forest city development and evaluation index
Planning	Masterplans e.g. Beijing Forest City Development Plan and Beijing Masterplan (2016 - 2035). Spatial planning for the core (e.g.50 pocket parks), central city area (e.g. parks, urban forests, park ring round city) and new forests elsewhere	March 2019, new integrated spatial planning bureau formed (integrating land-use, urban and rural, functional zoning, ecological red line delineation, sea and island planning)	Masterplans e.g. Huabei National Forest City Construction Plan and Huabei City Master Plan – includes Green Heart, Huabei UGS System Planning for urban greening construction	Masterplans for spatial planning aiming to make urban and rural green space more systematic and coordinated and connected and for forest city construction
Citizen Participation	Public participation is low. Mostly publicity campaigns e.g. eco-tourism, eco-cultural festivals, ecological anniversaries to promote awareness	Low levels of participation due to a range of factors e.g. political indifference, high costs associated with participation, feedback slow, inconvenient participation channels.	Interactive exchange platform set up on the municipal and county-level websites. Municipality set up Love Huabei mobile App and via WeChat official account of Huabei Release major documents released. Huabei Forestry Bureau holds science education activities. City actively promotes voluntary tree planting	Voluntary tree planting campaigns increasing significantly; Guangdong Forestry Bureau aims to use internet + voluntary tree planting to publicise activities. In 2020, 18.3 million people in the Pearl River Delta region voluntarily planted trees,

There are commonalities in the governance and urban planning of these cities, primarily due to China's centrally derived and hierarchical governance model. Particularly relevant to our analysis is the influence of the National Forest City Development Plan on the formulation of city-level Masterplans. Nevertheless, when comparing public participation, Beijing and Xiamen demonstrate relatively low

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levels of engagement, while Huabei stands out as quite proactive with the integration of digital technologies. In Hong Kong Guangzhou-Shenzhen, a similar focus on digital technologies is observed, particularly in the context of promoting voluntary tree planting. It is important to note that public involvement in these cities primarily revolves around raising awareness and encouraging tree planting, rather than extensive consultation or collaborative production.

We use two key comparative papers from CLEARING HOUSE in this chapter, selected because they provide comparisons of governance. The first key comparative paper by Zingraff-Hamed et al., (2020) offers a governance framework for NBS which we then applied to CLEARING HOUSE data used in the second comparative paper by Roitsch et al. (submitted). This paper also provides insights into co-producing UF-NBS from the perspective of city officials.

2.1 Governance models for NBS: seventeen cases from Germany [comparative paper].

Zingraff-Hamed, A., Huesker, F., Albert, C., Brillinger, M., Huang, J., Lupp, G., Scheuer, S., Schlatel, M. & Schroter, B. (2020) Governance models for nature-based solutions: seventeen cases from Germany, *Ambio* 50: 1610 – 1627.

The first comparative paper, while not focusing on urban forestry, provides valuable insights into the governance of NBS. It highlights a critical point that NBS implementation is often slowed down by governance barriers. Focusing on NBS implementation for flood risk management and mitigation in Germany, the paper identifies the governance models that were applied and explores the differences. Their results reveal governance models for NBS based on their seventeen cases in Germany and those found in literature (Table 2.4). Of particular relevance for D2.2 and this Chapter is the governance model for NBS in Table 2.4 (highlighted in light green).

Table 2.4 Synthesis of the main results of the governance model typology

Governance models identified	Dimensions	Description	Politics	Reference
• **Hierarchical;** • **Network;** • **Market.**	Formality of institutions and the role of state versus non-state actors	The hierarchical style is characterized by the dominant role of the government, while the network mode includes all forms of cooperation between government and non-state actors. In the market mode, the government delivers services to non-state actors but choices are free and ruled by prices and negotiations	Water	Conceptual paper by Pahl-Wostl (2015)
• **Hierarchical;** • **Co-governance;**	Role of governmental and non-	Hierarchical governance has at one end of the spectrum a top-down influence by the government and at the other	No specific politics	Conceptual book by Kooiman (2003)

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• **Self-governance.**	governmental actors	end, self-governance where actors are not controlled by government. Co-governance where public and private actors interact with each other is located in between the two ends		
• **Hierarchical;** • **Closed co-governance;** • **Open co-governance;** • **Self-governance.**	Actors, power and rules	Amplification of Kooiman´s spectrum by dividing co-governance as closed and open co-governance. Closed co-governance contains a selected mixed group of actors, restricted cooperation and pooled power relations while open co-governance contains a large mix with diffused power and flexible rules of cooperation	Nature policy	Example of Utrechtse Heuvelrug 1970s & 1980s, Netherlands by Arnouts et al. (2012)
• **Coercion;** • **Voluntarism;** • **Targeting;** • **Framework regulation.**	State intervention versus societal autonomy but along the three dimensions of polity (political form), policy (policy content) and politics (political processes)	This typology puts emphasis on the role and the self-empowerment of the state and integrates the European multi-level governance system. Important criteria are, whether legislation is binding; and whether implementation is rigid	European Union	Conceptual paper by Treib et al. (2007)
• **Hierarchies,** • **Markets, and** • **Community-based approaches**	Power of decision making and resource allocation	Hierarchies are based on command and control and resource allocation occurs through authority and power structures. Market-based approaches are driven by the voluntary exchange among individual actors, and resource allocation is based on willingness to pay. Community management is based on cooperation among actors, and resource allocation is considering individual as well as common goals	Ecosystem Services	Conceptual paper by Vatn (2010)
• **Centralized;** • **Decentralized;**	Actor features, institutional	Models are distinguished according to initiating actors,	Environmental governance	Driessen et al. (2012) Apply

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• **Public–Private;** • **Interactive;** • **Self-governance.**	features and feature contents	stakeholder position, policy level and power base (actor features); model of representation, rules of interaction, and mechanism of social interaction (institutional features); and goals and targets, instruments, policy integration, and science-policy interface (features content)		an environmental governance conceptual framework to a 20-year period in the Netherlands
• **Self-governing;** • **Governing by provision;** • **Governing by authority;** • **Governing through enabling.**	Government vs. other actors	Governance modes vary according to the capacity of local government and practice to deliver particular forms of services and resources up to the traditional forms of authoritarian regulation	Climate	Examples from UK and Germany in paper by Bulkeley and Kern (2006)
• **Cooperation and Initiatives;** • **Co-Design;** • **Citizen Power;** • **Top-down.**	Framing and implementing organizational structures. Project Coordination. Participation level. Institutional setting. Financing model. Property rights, constellation and localization	Governance models range from more participation and private funding to more top-down ruling and state funding	NBS	Zingraf-Hamed et al. (2020) used 17 cases of NBS for flood mitigation in Germany

This paper delves into the diverse governance models that underpin 17 NBS implementations in Germany, aimed at mitigating flood risks. It offers valuable insights for those engaged in the investigation, design, and successful execution of NBS initiatives. The research underscores the notion that multiple governance models can drive NBS implementation, dispelling the notion of a universal, "one-size-fits-all" approach. Nevertheless, a pivotal common thread runs through these models—the inclusion of diverse stakeholder groups. This highlights the indispensability of collaborative governance approaches in the effective realization of NBS projects. The study emphasizes that a heightened level of cooperation among stakeholders enhances the potential for NBS implementation. The European Union's intent to promote NBS through polycentric governance is acknowledged; however, the presence of local, historical, and cultural variations in governance practices poses

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challenges to seamless collaborative planning. Contextual conditions exert a palpable influence on the choice of governance models. Therefore, the systematic analysis of governance models within NBS research projects becomes imperative. The future landscape of governance will confront the task of adapting conventional models to accommodate larger-scale solutions involving a multitude of stakeholders. In its investigation, the study underscores the critical roles of municipalities, citizens, and non-governmental organizations (NGOs) within the stakeholder constellation essential for NBS design and implementation. This contribution fills a crucial gap, as it sheds light on the significance of empirical, evidence-based research on governance structures for NBS. Intriguingly, despite the seemingly intuitive importance of on-the-ground stakeholders in the NBS process, many governance systems have yet to formally recognize their role and contributions.

In sum, this research not only enriches our understanding of governance models within NBS implementations but also reinforces the pivotal role of collaborative governance and the diverse spectrum of stakeholders in shaping the success and sustainability of NBS initiatives. It serves as a valuable resource for guiding future research, policy development, and practical endeavours in the realm of NBS and provides a governance framework for NBS that we use in the next section (see Table 2.5).

2.2 Co-production of urban forests as nature-based solutions: motivations and lessons-learnt from public officials [comparative paper]

Roitsch, D., da Schio, N., Krajter Ostoić, S., Zivojinovic, I., Vuletić, D., Armstrong, A., Czaplarska, A., Baró, F., Whitehead, I., Buijs, A. and De Vreese, R. (submitted to *Environmental Science and Policy* in August 2023, currently under review). Co-production of urban forests as nature-based solutions: motivations and lessons-learnt from public officials.

The second comparative paper includes seven European case study cities, three of which are core CLEARING HOUSE case study cities, namely, Brussels (Belgium), Gelsenkirchen-Ruhr (Germany) and Krakow (Poland). The remaining four case study cities are Wroclaw (Poland), Sarajevo (Bosnia and Herzegovina), Zagreb (Croatia) and Essen (Germany). Interviews were carried out with 22 public officials working in those cities between March and July 2022. The selected public officials needed to professionally work in urban forestry, urban greening, NBS, or closely related fields; and they needed to have experience with interventions and initiatives applying a co-production approach.

Underpinning this paper is the understanding that UF-NBS can address societal challenges (e.g., climate change, air pollution, biodiversity loss) and are closely tied "to actions for the expansion, protection, restoration, and maintenance of the urban forest" (Scheuer et al., 2022).

The paper illuminates the potential benefits of co-production in the realm of urban forests as nature-based solutions (UF-NBS). Co-production models not only foster innovative business approaches but also provide avenues to bridge the gap between urban forest initiatives and policymakers, thereby demonstrating the multifaceted benefits of investing in green spaces. However, the success of co-

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production hinges on several factors, including creating a sense of ownership and responsibility, raising civic awareness, providing education through action, and showcasing positive cost-benefit analyses. Furthermore, the study emphasizes the need for training and capacity building among public officials and urban foresters, who may require a shift in their traditional mindset and skill set to engage effectively with diverse stakeholder groups. While co-production holds promise, it also brings to light the challenge of potential exclusion of marginalized groups and the de facto shift of power towards more privileged segments of society in a context of austerity and state disengagement from urban forest management. This multifaceted exploration underscores the evolving landscape of urban forestry and the complex interplay between citizen participation, governance, and ecological sustainability. It is also essential to note that this shift in governance dynamics comes at a time when urban forest management faces challenges, such as shrinking public budgets due to austerity measures and neoliberal principles, as highlighted by Van der Jagt et al. (2016).

For this deliverable (D2.2), we utilized the framework developed by Zingraf-Hamed et al. (2020) to conduct additional analysis[3] for this Chapter (see Table 2.5). Table 2.5 represents an extension of data previously analysed in the draft by Roitsch et al. (submitted) and additional analysis conducted by the main author of deliverable 2.2. Table 2.5 highlights 10 UF-NBS projects located in three European cities that were part of the CLEARING HOUSE project and one which was not (Wroclaw, Poland). The table provides summary analysis of each project, including its description, driving factors, participation level (according to the governance model developed by Zingraf-Hamed et al. in 2020), financial resources, and the project's timeframe.

Table 2.5 Analysis of co-produced UF-NBS projects in four European Cities

City	UF-NBS Project	Description	Drivers	Participation Level	Financial Resources	Time Period
Kraków (KRA)	Drwinka River Park	A wild river park that due to residents establishing the Drwinka River Park Association & pressuring the city government has been protected from property developers	Interest pressure group of residents	Citizen power	Participatory budget	Since 2014

[3] As of the time of submission, the second key comparative paper authored by Roitsch et al., was submitted to a peer-reviewed journal.

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Wroclaw (WRO)	Grow into Wrocław	Biannual tree planting by residents to symbolize their newly born children.	Tree planting. Since 2017, residents planted 2333 trees	Cooperation and initiatives	City of Wroclaw budget	Since 2017
Gelsenkirchen/Ruhr area (GE)	Project "Industriewald Ruhrgebiet"	Green inner-city development through natural succession on post-mining areas. Promoting green forest wilderness within the cities of the Ruhr area is.	Idea originated from the International Building Exhibition Emscher Park; operated today by the North Rhine-Westphalia State Office for Forestry and Wood ("Wald und Holz NRW")	Cooperation and initiative	Financing for personnel and forestry machines by "Wald und Holz NRW"	Since 1996
	PlanBirke plus C	Citizen science research on birch trees in the context of climate change, biodiversity, and water retention.	Forestry in crisis mode; adaptation to climate change	Cooperation and initiative; Co-design	Forest Climate Fund (includes Federal funds)	Since 2022
	Project "GE grünt" (GE is green)	Development of an environmental sensor network in conjunction with a green citizens' budget for climate adaptation measures	Extreme weather events (heat, heavy rain); Expansion of citizen participation in the topic of sustainability; Federal funding program (Germany) to strengthen smart cities	Cooperation and initiative	Federal funding program (Germany) "Model Projects Smart Cities"	Since 2022
	"Zukunftsstadt 2030+" (Future city 2030+)	Exploring what the city of tomorrow should look like by applying educational approaches and	City of the Future competition by the Federal Ministry of Education and Research in 2015	Cooperation and Initiatives; Co-design	Approx. 1.65 million EUR	Since 2018

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		participation processes in neighbourhoods on the example of four real laboratories.				
Brussels (BXL)	Plants for Environmental Transition and Life (PETAL)	Aimed to collectively experiment with ways to develop and manage the presence of plants in the streets to meet the needs of stakeholders while welcoming nature.	Participatory Action Research project to explore ways in which plants can combat urban pressures (UHI, air pollution etc.)	Co-design	Innoviris – Co-Create Call regional grant	2018-2021
	Park of the Dew (Le Parc de la Rosee)	The development of a small neighbourhood park from abandoned land to a green park.	The development of a small neighbourhood park from abandoned land to a green park.	Co-operation and co-design	City approached Brussels Environment IBGE	1997 - 2001
	SAULE (Symbiosis Urban Agriculture Housing Environment) project	Co-create intervention for the development of an urban agriculture project involving the local community.	Demographic growth. the demand for affordable housing and agriculture in the city. Using the garden city model to eat and live in the same neighbourhood.	Cooperation and Initiatives; Co-design	Three-year research project with ERU - Cooperative of Urban Studies and Research and FCC	2017-2020
	Parckfarm	Developing a new park concept: an edible park with a socio-ecological purpose and including the reappropriation of public green space by citizens.	Project was born out of the Parckdesign Festival in 2014 which promoted participatory development of public green space, with attention to creative and artistic practices.	Cooperation and Initiatives; Co-design; citizen power	In 2014, public institutions invested to improve development of the site. Citizens then created a non-profit association to continue.	From 2014

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	Brussels Ecological Network	Strengthening nature as part of the Nature Plan in Brussels by collecting feedback from local stakeholders.	To reconnect green spaces and develop biodiversity, nature and the quality of life in the city.	Top down; cooperation	Public regional funds: 165.000 € for the prospecting, communication and project designing. Private sector investment.	From 2011

Table 2.5 provides a comparison of UF-NBS CLEARING HOUSE city projects. It reveals that key drivers of co-producing UF-NBS in these cities are an exhibition, festival or competition (Gelsenkirchen and Brussels); research funding (Gelsenkirchen and Brussels), ecological crisis/disconnection or land development (Brussels, Gelsenkirchen), a pressure group (Krakow) and cultural associations of nature (Wroclaw) i.e. tree planting for new-borns, symbolising new life thus viewing nature as part of ritual and folklore practices. Participation levels mostly involve cooperation and initiatives, with some including co-design. Only one project involves citizen power (Krakow), and one was a top-down initiative that also involved cooperation from local stakeholders (Brussels). Funding ranged from city, regional and federal with one including private finance.

The remainder of this report elaborates on two key aspects revealed in the comparison of governance and management of UF-NBS – sustainable funding mechanisms (Section 2.3) participation levels (Section 2.4 on citizen science).

2.3 Comparison of sustainable funding mechanisms of UF-NBS and cost-effectiveness [comparative report]

Biaz, L. (2022) *Sustainable funding mechanisms for UF-NBS and cost-effectiveness,* Work Package 2, Task 2.2, Workstream 3, LGI Consulting, H2020 project CLEARING HOUSE, agreement no. 821242.

The key deliverable from WP2, Task T2.2, Workstream 3 entitled **Sustainable funding mechanism for UF-NBS & cost-effectiveness** includes a comparison of three of the five CLEARING HOUSE European case study cities (Barcelona, Gelsenkirchen and Krakow) and one from China (Hong Kong). Other cities included in deliverable T2.2 are Milano and Padova (Italy) and Paris (France) therefore, we include them where there is comparable information.

The **share of the municipality budget allocated to UF-NBS is low** (see Figure 2.1). Krakow in Poland has the highest share spent on UF-NBS compared with other municipalities in the study, but this is still only 2 %. Within this budget, both maintenance (inventory of trees, salaries, equipment and water resources and implementation (land purchase, if needed), project preparation, new plants (mainly trees) are costs that are covered. AMB (Barcelona) has 0.94 % which is approximately 12M€ and this

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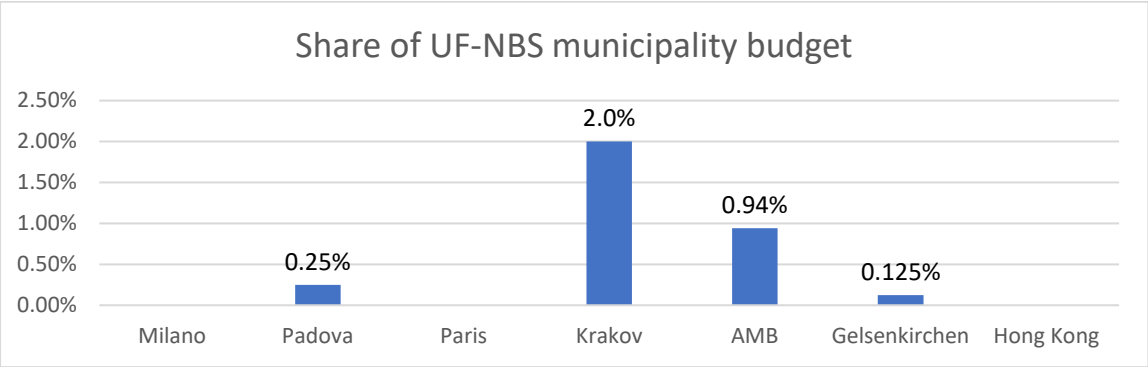
is for maintenance of the metropolitan park network. Hong Kong has 0.25 % allocated and between 2016 – 2017 the core tree management departments spent 411 million Hong Kong dollars approx. 50 million €) in tree management which includes tree care, facility maintenance, horticultural care, greening, etc. but excludes staff remuneration and country park management. In Gelsenkirchen (Germany), only 0.125 % is allocated to tree maintenance which is low considering trees cover a large part of the city. There was no comparable data available for Milano, Paris or Hong Kong.

Figure 2.1 Share of UF-NBS Municipality Budget (Source: Biaz, L., 2022, T2.2)



The **share of the budget per tree** in order to maintain them in the street, alleys, parks and urban forests, municipalities allocate part of their overall budget to cover the different costs. Gelsenkirchen in Germany allocates 194 euros per tree which in comparison to Milano and Padova in Italy (average 25 euros per tree) seems a lot. However, this is due to the interval of maintenance (yearly for Milano and Padova) and a longer time horizon for Gelsenkirchen. Barcelona (AMB metropolitan area), Krakow, Paris and Hong Kong were not able to provide data on this theme.

The comparison of cities reveals that some cities employ scientific tools or seek assistance from external experts for mapping purposes. In the case of Barcelona (AMB), cost evaluations are conducted internally on an annual basis. This process also involves collaborations with research institutions and consulting firms to facilitate a comprehensive assessment. The duration over which the benefits are assessed varies, contingent upon the specific study and the availability of resources.

In contrast, other cities that participated in the CLEARING HOUSE study do not quantify the benefits of UF-NBS. Instead, cities like Gelsenkirchen, Padova, Krakow, Paris, and Hong Kong approach the assessment qualitatively, focusing on aspects such as ecological advantages and social cohesion.

Notably, in Hong Kong, the term UF-NBS is not widely adopted, particularly in relation to trees. The predominant practice for funding tree planting in Hong Kong heavily relies on government initiatives. While the private sector does play a role in planting and maintaining landscapes, developers and management primarily view trees as amenities. Recognizing private trees as public resources is not a widespread practice within the private sector.

Cost-effectiveness is not typically used as a compelling argument for implementing UF-NBS, however, cost-effectiveness could be a persuasive factor in favour of forests compared to parks, as the

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maintenance costs of forests are considerably lower. Nevertheless, the significant barrier to establishing forests in urban settings remains the availability of suitable space. The choice of locations for implementing UF-NBS varies according to the unique context and land availability in each city. For instance, in Gelsenkirchen, the selection of UF-NBS planting sites is influenced by historical, geographical, and legal factors. In Krakow, decisions are primarily tied to historical considerations and ownership status (private or public). In Milan, factors such as the source of funding (public or private), priority level, and the availability of new areas exert a more substantial influence on the decision-making process.

2.4 Citizen science and UF-NBS [comparative reports]

Scheuer, S., Wolff, M., Mishra, H.S., Tyrväinen, L., Haase, D. (2022) *CLEARING HOUSE citizen science methodology* (M3.9). H2020 project CLEARING HOUSE, agreement no. 821242.

This chapter is written using M3.9 (Scheuer, S. et al., 2022) and additional contributions (Box) and comparative tables (Table 2.6, 2.7) from Himansu Mishra and Liisa Tyrväinen (Natural Resources Institute Finland, LUKE)

Citizen Science and UF-NBS

Citizen Science (CS) involves active participation of the public in scientific research, leading to tangible outcomes such as the generation of scientific knowledge and policy adjustments. In recent years, there has been a notable upsurge in CS projects related to urban biodiversity monitoring, specifically focusing on the identification of woody plants and urban trees that contribute to the enhancement of ecosystem services. In urban forestry, the utilisation of Voluntary Geographic Information (VGI), has emerged as a vital area where CS plays a pivotal role, aiding in participatory planning and conflict resolution. Various map-based tools, such as the Public Participation Geographic Information System (PPGIS), are employed for conducting ecosystem assessments and pinpointing hotspots of ecological significance and human activity. Data obtained through PPGIS in the realm of CS are indispensable for mapping the interplay of benefits and trade-offs within urban forests and play a crucial role in accurately assessing ecosystem services. These map-based applications and spatial data visualization tools are instrumental in fostering collaboration across different sectors, engaging citizens in the planning process, and raising public awareness about the significance of urban green spaces. However, challenges persist in evaluating Cultural Ecosystem Services (CES) in comparison to ecological ecosystem services (EES) within urban forests. Unlike ecological services, cultural services in natural environments are closely interlinked with other ecosystem services and significantly impact the quality of provisioning and regulatory services. Ecosystems do not directly produce cultural services but rather facilitate them through meaningful interactions between humans and nature, influencing how individuals perceive and value a specific ecosystem and its components.

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From the analysis of reports (D2.1, da Schio et al., 2021; D3.2, De Vreese et al., 2021), project partner LUKE identified a set of key themes, knowledge gaps, barriers and corresponding actions that need to be addressed through citizen science in the European city case studies (Table 2.6, Table 2.7).

Table 2.6 Comparative identification of knowledge gaps related UF-NBS in the EU city case studies.

Themes	Knowledge gaps	City
Baseline condition study of UF-NBS (private and public land)	Private garden tree and garden information (forest or single tree and permeability)	Brussels
	State of the soils in the city and contribution towards diversified plant development *(private gardens)*	Brussels
	Tree information *(i.e. lack of growth, tree and crown damage, drought stress)*	Leipzig
Ecosystem services	Citizens' understanding of the comprehensive and diverse ecosystem services and values of UF-NBS, the use and management of natural resources.	Gelsenkirchen, Leipzig, Kraków
	Citizen needs and demands and the supply of green areas and cultural ecosystem services.	Gelsenkirchen, Leipzig, Kraków
	The link between the presence of the ecological network and the presence of certain species.	Brussels, Barcelona
UF-NBS management	Suitable and cost-effective methods for citizens to create, manage, and protect UF-NBS without losing biodiversity.	Kraków
	Insufficient data about key cultural ecosystem services of UF-NBS.	Barcelona
Climate change adaptation	Local knowledge about biodiversity, environmental, and bio-physical features of UF-NBS *(Climate adaptive reforestation and species)* is important for ecological continuity and minimise urban heat island effect.	Kraków, Leipzig, Barcelona
	Public knowledge about the impact of trees on urbanisation and urban pollution on tree ecosystems.	Brussels
Note: Case study cities: **1**- Gelsenkirchen, Germany; **2**- Kraków, Poland; **3**- Leipzig, Germany; **4**- Llobregat Valley (Lower Llobregat Valley), Spain; **5** -The Sonian City Belgium		

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Table 2.7 Comparative analysis of the barriers to citizen science related to UF-NBS in the EU city case studies

Themes	Barriers	Actions for Citizens Science	Case Study City
Land use conflicts	UF-NBS quality and use (1); active users of UF-NBS and commercial and real estate developers (2); improvement of green areas and risk of degradation due to overuse (2).	Evaluate citizen perception about the land use conflicts with UF-NBS in the locality and in the city. The impact of real estate and commercial development on UF-NBS in the locality and the city. Evaluation of different UF-NBS environment types and the assessment of the risk of degradation.	Gelsenkirchen, Kraków
	Poor accessibility conditions to green space.	Evaluation of accessibility conditions of UF-NBS in the locality and the city (small-large green spaces).	Leipzig
	Existing vehicular roads pose challenges for ecological connectivity.	Evaluate citizens' appreciation of UF-NBS replacing car-intensive wider streets and parking spaces.	Brussels
Urbanisation	The urbanisation of river landscapes in the locality and the city (2,4); Intensive land development and reduction of green areas (5); Parking reduce green space and ecological connectivity (5).	Evaluate citizens' perception on the impacts of urbanisation and intensive land development of urban river landscapes/ exiting green areas/ urban ecological connectivity.	Kraków, Barcelona, Brussels,
Landscape fragmentation	Fencing of private properties due to legal concerns and privacy reasons (3,5).	Evaluate citizens' perception of the current private garden fencing conditions.	Leipzig, Brussels
Ecological connectivity and biodiversity	Alteration of ecological process of existing green spaces (UF-NBS) (4); Fragmentation of urban ecological connectivity (4, 5); landscape fragmentation and agricultural intensification (4); Agricultural land as biodiversity desert (5).	Identifying urban features leads to ecological/ landscape fragmentation and evaluation of the impact on urban biodiversity (fauna diversity) using citizen science. Evaluate citizens' appreciation of physical or policy interventions to reduce ecological fragmentation.	Barcelona, Brussels,
Climate change adaptation	Degradation of urban environmental quality.	Citizens' understanding of the features leading to degradation of the quality UF-NBS in the locality and the city.	Kraków, Barcelona

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	The danger of river floods, climate change consequences, high and low regimes of water.	Citizens' evaluation of the urban environmental issues, i.e. flooding, heat, drought, and citizen appreciation of the role of UF-NBS in mitigating those effects in their locality and the city.	
	Watering vegetation during drought or dry summer periods (1, 3 4).	Citizens' knowledge about UF-NBS or single tree conditions during dry summer and drought conditions in their locality and the city.	Gelsenkirchen, Leipzig, Barcelona
	Presence and abundance of exotic species (4) / Insufficient conservation efforts of protected species (4).	Identification of exotic species and appreciation of the need for conservation efforts for protected species.	Barcelona
Political and administrative barriers	Nature conservation laws restrict access and use of protected areas.	Citizens' perceptions about nature conservation legislations and efforts restrict access and use of conservation areas.	Leipzig
	Poor equipment or design of public parks is regarded as an institutional barrier in planning and design.	Citizens' preferences for green space (UF-NBS) for their design and environmental quality, and services and amenities.	Leipzig
Education and awareness of UF-NBS management	Despite best practices, citizens lack knowledge about UF-NBS services and benefits (1,4).	Evaluate citizen awareness about UF-NBS services and benefits.	Gelsenkirchen, Barcelona
	Poor management of private gardens and trees.	Citizen awareness about effective and sustainable tree and forest management techniques (use of pesticides, watering in dry periods)	Brussels
Note: Case study cities: **1**- Gelsenkirchen, Germany; **2**- Kraków, Poland; **3**- Leipzig, Germany; **4**- Llobregat Valley (Lower Llobregat Valley), Spain; **5** - The Sonian City Belgium			

The five European city case studies presented here provide insights into the common issues, knowledge gaps (Table 2.6) and barriers (Table 2.7) faced by cities in implementing urban forest-nature-based solutions (UF-NBS) and citizen science approaches . One of the key challenges faced by all cities is the fragmentation of green spaces, particularly in the urban core. All cities have identified the need to create more accessible green space and improve the quality and distribution of green space to ensure equitable access for all citizens. Another common challenge identified by these case studies is the need to meet the multifunctional demands on urban green space, such as recreation, biodiversity protection, air quality, and climate change adaptation. These demands, however can have

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considerable synergies. For example, cities need to balance the need for green spaces to mitigate the urban heat island effect while also providing recreational opportunities for citizens. Citizen science approaches can help identify and inform the decision-making and also help prioritising these sometimes even competing demands from urban forests.

3 THE GEOGRAPHY OF UF-NBS: EXPLORING QUESTIONS OF CONNECTIVITY AND ACCESSIBILITY

The geography of UF-NBS was largely translated into a place-based and patch-specific perspective for conceptualizing and assessing the multiple functions of the underlying service providing units. However, accounting for the relational and interdependent way of both the social and biophysical landscape characteristics would help us in understanding who experiences which ecosystem services and where and how planning responses are needed in case of service-scare areas.

Consequently, in this chapter, we integrated the concepts of networks into an UF-NBS framework from a social-ecological perspective. This is essential especially in urban areas due to their fine-scale and dynamic landscape patterns affect movement of people and wildlife across cities. We aimed to foster the understanding of ***connectivity*** (e.g., the movement of organisms) and ***accessibility*** (e.g., the movement of people) within the dense urban matrix and under changing ***urbanization pathways***: How are urban tree systems connected? And how accessible are woody green spaces for the residential population?

The accessibility of green and blue space plays a pivotal role in complex human-environmental systems, especially within cities. Green and blue space refers to the interconnected network of natural elements such as parks, gardens, reserves, forests, lakes, ponds, and rivers. These areas provide a wide array of ecosystem services and socio-economic advantages, making their accessibility a matter of significant importance. Accessibility, in this context, refers to the capacity to reach and engage with green and blue spaces, enabling various benefits like physical activity, recreation, health, well-being, and social interaction. As cities experience rapid population growth, especially in terms of physical expansion, the accessibility of green and blue spaces becomes paramount for green space planning and management. European urban planners generally favour the concept of the compact city, characterized by high density, mixed land use, efficient public transport, and a strong emphasis on walkability. However, this approach faces a paradox: the more compact a city becomes, the more people can benefit from green and blue areas but it also exerts greater pressure on the ecological functions of green and blue space. Therefore, mapping and quantification of green and blue spaces to assess the degree of accessibility and the fairness of flows (i.e. how just are the flows of people in, out and around green and blue spaces) is vital for environmental justice concerns. The papers summarised in the remainder of this section contribute to these debates and offer new insights on: accessibility and the functional connectivity of urban tree systems, comparing five city case studies - Leipzig, Kraków, Gelsenkirchen, Barcelona, and Brussels (Section 3.1); the role of brownfields for functional connectivity of urban tree systems in Leipzig (Section 3.2); conceptualising barriers to urban green spaces (UGS) drawing on the cities of Stockholm, Leipzig, and Lodz (Section 3.3); measuring

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accessibility to green and blue space using spatial analysis, drawing on the case of Halle, Germany (Section 3.4); the physical barriers of and in green space in Halle, Germany (Section 3.5) and the impact of large-scale and rapid afforestation on green space patterns in Beijing, China (Section 3.6).

3.1 Accessing the functional connectivity of urban tree systems [comparative report]

Wolff, M. & Haase, D. (2022). Accessing the functional connectivity of urban tree systems. Report for Stream 4: Geography of UF-NBS / Multifunctionalities, T2.2 Conducting a comparative, in-depth analysis of case study cities, CLEARING HOUSE.

From an ecological point of view connectivity is the degree to which a landscape facilitates or impedes movement of organisms within a network of resource patches. In line with this, a report (T2.2) on Accessing the functional connectivity of urban tree systems in the five case study cities of CLEARING HOUSE, namely Leipzig, Kraków, Gelsenkirchen, Barcelona, and Brussels, detected how urban green systems are functionally connected against the background of the dominating land use, and to what extent the protection and management of areas in cities might enhance this connectivity.

Using a set of established (share of canopy, tree cover density) and novel (overall connectivity, connector value, see this link for more details) indicators this report reveals significant differences between the five case study cities in terms of connectivity characteristics of urban tree systems (Table 3.1).

Table 3.1 Profile of characteristics for connectivity of urban tree systems in five case study cities

	City	Barcelona	Brussels	Gelsenkirchen	Kraków	Leipzig
Network	Network coverage [share canopy]	above average	above average	below average	average	below average
	Network complexity [ratio between nodes and edges]	average	average	below average	above average	above average
	Network connectivity [overall connectivity]	average	above average	average	below average	below average
LU variation	Dominant LU for overall connectivity	Forest	Forest, leisure area	Natural grassland	Forest, agricultural land, natural grassland	Forest, agricultural land
	Dominant LU for steppingstones	Forest, natural grassland	Forest, leisure area	Natural grassland, leisure areas	Natural grassland	Forest, leisure and park areas
Protection	Protection of patches relev. for	below average	above average	average	below average	above average

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	overall connectivity					
	Protection of patches relev. as steppingstones	below average	above average	average	average	above average

It was demonstrated that the interplay of indicators is required in order to display a full picture: while some cities like Barcelona have an above average coverage of relevant tree patches, their overall connectivity range within the average of the sample. In Leipzig, the corresponding canopy share as well as the resulting connectivity is below average as a result of the strong fragmentation of the tree patches giving Leipzig the most complex network with big challenges for the connectivity potential. Furthermore, forest land use appears to be the most relevant socio-ecological domain with respect to overall connectivity of the network as well as for the role as steppingstone. However, as the detailed maps in T2.2 display, there are tremendous differences with respect to location of individual nodes and their role for the whole network system as well as their connectivity function for the immediate surrounding. In particular for cities in which large forest areas are located at the inner fringe, other land use categories became relevant as steppingstones such as leisure areas, parks, and even natural grassland with few trees. Both results, network characteristics and land use variations, play a central role for the question of which area should be protected. As in particular steppingstones do not rely so much on the availability of forest areas, the emerging share of protected stepping stone potential is lower than the corresponding share of protected overall connectivity potential in each city – in particular in Barcelona. Finally, T2.2 demonstrated a potential application of the functional network of urban tree systems in the case study Kraków, the city with the lowest share of protected overall connectivity. Estimating potential routes between important habitat nodes can help to detect where densification should be avoided, and a potential protection or other management could play a role for maintaining or even strengthening the connectivity of the urban tree system.

3.2 The role of Brownfields and Their Revitalization for the Functional Connectivity of the Urban Tree System in a Regrowing City [Single City Paper]

Wolff, M., Haase, D., Priess, J., Hoffmann, T.L. (2023). The Role of Brownfields and Their Revitalization for the Functional Connectivity of the Urban Tree System in a Regrowing City. *Land* 12, 333.

Complementary to the work outlined in Comparative Paper I, the paper in this section studies different metrics for functional connectivity in the case study city of Leipzig, Germany.

The connectivity of green infrastructure facilitating the movement of organisms is the key to strengthening biodiversity in cities. Brownfields are a valuable land resource, with their revitalisation as a NBS high on the policy agenda. In supporting cities which simultaneously aim for densification and the maintenance or further development of greenery, this paper develops a model for identifying and prioritising the role of revitalised and prevailing brownfields for the connectivity of green

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infrastructure using the example of Leipzig, Germany. Given the fact that Leipzig will remain the fastest growing big city in Germany with an estimated population increase of 14% up to 2040, evidence-based support of land use decisions is needed more than ever. To assist this decision, this paper used an ecological network model (Graphab) for the functional connectivity of the Urban tree System (UTS), based on high-resolution and cadastral data in the city of Leipzig.

Comparing metrics between land use categories, brownfields contribute to the overall potential of stepping stones with a significant share of 13%, while revitalised brownfields substantially contribute to global connectivity, with a value of 87% being equally important, for example, with Leipzig's central parks. The research uncovered, prioritised, and visualised the role of revitalised and existing brownfield sites accounting for the complexity of multiple associations between nodes of the broader green infrastructure network. In order to balance the need for densification, as well as for the maintenance, further development, and qualification of urban greenery in Leipzig, the paper (a) distilled lessons learnt from the hitherto revitalisation strategies, (b) detected strategic functional connectivity corridors contributing to establish overall connectivity for urban wildlife conservation, and (c) provided a tool for prioritising brownfields which needs to be kept for ensuring functional connectivity of the green infrastructure, those which could potentially be densified, and those which need to be renatured fostering the functional connectivity of the city.

To what extent brownfields facilitate the ecological movement and biodiversity within the city, or how revitalisation measurements foster this functional connectivity of the whole green network, are, among others, blind spots in the current planning strategies of many cities. In contrast, brownfield revitalisation is one of the most important NBS strategies in cities. Given the wide absence of spatial-explicit taxa data and data-processing know-how in many city administrations, this paper presented an approach using freely available software tools and high-resolution canopy data as a proxy for functional connectivity which serves as a blueprint for implementation in other cities.

As decision-makers are challenged by the question of whether or not a brownfield could be renatured or densified, the application of the proposed approach can (a) be used as an ex-ante evaluation of NBS strategies with comparably low effort in data obtaining and processing, (b) be used to reduce or avoid costs of possible wrong land use decisions, (c) provide a complementary perspective compared to widely used place-centric assessments of individual patches or areas, and (d) form a standardised tool for a continuous and comparable monitoring in line with current international recommendations[4]. All of these aspects will be required in order to balance urban development and ecological protection and biodiversity in our cities.

The applied spatial-explicit network approach provides a complementary planning tool for prioritizing brownfields and the added value of their renaturing by identifying (a) strategic functional corridors formed by brownfields, (b) the connectivity relevance and exposure of individual brownfields, and (c) how renatured brownfields would strengthen existing corridors and form alternative paths.

[4] IUCN. The IUCN Urban Nature Indices: A Methodological Framework; IUCN: Cambridge, UK, 2022; 32p.

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3.3 Conceptualising multidimensional barriers: a framework for assessing constraints in realising recreational benefits of urban green spaces [conceptual paper]

Wolff, M., Mascarenhas, A., Haase, A., Haase, D., Andersson, E., Borgström, S., Kronenbergt J., Laszkiewicz E. & Biernacka, M. (2022). Conceptualizing multidimensional barriers: a framework for assessing constraints in realizing recreational benefits of urban green spaces. *Ecology and Society*, 27(2).

While the accessibility of potential UGS is a widely discussed topic, the specific barriers that impact accessibility are often underestimated. These barriers don't simply equate to limited or uneven access, nor are they solely related to physical aspects. Instead, the array of barriers, including their intricate interactions encompassing people's perceptions, personal circumstances, and institutional frameworks, renders this issue complex and challenging to implement in practical urban planning. Recognizing the pivotal role of barriers in influencing people's choices, Wolff et al., (2022) present a conceptual framework designed to capture the cumulative and interactive effects of various barriers on the realization of recreational benefits from UGS.

This framework categorizes barriers into three broad dimensions: physical, personal, and institutional, and underscores their interplay through insights gained from three case studies in Stockholm, Leipzig, and Lodz. They argue that the constraints on the accessibility of UGS primarily stem from how beneficiaries perceive and experience these barriers. Their examination of barriers aims to enhance understandings of why individuals might not utilize UGS and enable us to draw conclusions about the actual accessibility of recreational benefits.

Derived from the conceptual framework, they identify three pathways for enhancing accessibility to the recreational benefits of UGS: environmental enhancements, knowledge dissemination, and community engagement. They contend that these pathways should not be pursued as vague objectives but as a nuanced, context-dependent recalibration of individual, physical, and institutional factors to promote fairness in environmental and green space planning and management. Through this systematic conceptualization and classification of multidimensional barriers, the aim is to foster a more comprehensive understanding of individuals' decision-making processes when it comes to accessing recreational benefits.

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3.4 Taking one step further: Advancing the measurement of green and blue area accessibility using spatial network analysis [single city paper]

Wolff, M. (2021). Taking one step further–Advancing the measurement of green and blue area accessibility using spatial network analysis. *Ecological indicators*, 126, 107665.

A corresponding paper uncovered differences between accessibility measurements using the case study of Halle. Accessibility, the ability or possibility to reach and engage with green blue areas, can be conceptualized by three different perspectives – Buffer Analysis (BA), Network Analysis (NA) and Distance-Decay Analysis (DDA). However, these perspectives have not been systematically and illuminated in combination nor have associated methods been contrasted to each other. This paper focused on three spatial accessibility methods testing their explanation power for the two widely applied conceptualizations, population pressure and green blue area provision. While all methods differ in terms of complexity, data requirements, merits and pitfalls, they are hardly able to combine different conceptual perspectives, nor do they sufficiently display the proximity perspective. Consequently, and complement to established methods, this paper suggests indicators which characterize the service connecting areas between green blue areas and their potential users. In particular, the suggested Local Significance in combination with the Detour Index are flexible and powerful proxies for characterising connecting edges and indicating how well people can actually walk along these routes and how spatial barriers might constrain these potential flows.

In calling for an increasing attention paid by planners to the importance of a combined perspective of provision and pressure in finding green blue area solutions, this paper underlines the relevance of network characteristics for a proper monitoring of green blue area accessibility. This monitoring emphasized the walkable environment surrounding green blue areas and resident's homes what is even more challenging in ever growing and densifying urban environments. In particular, the novel indicators developed are flexible and powerful proxies for connecting edges indicating how well people can actually walk along these routes and how spatial barriers might constrain this potential flow along service connecting areas.

Against this background, the results presented provide an important methodological contribution for approaches to accessibility assessments within the field of green blue area studies and, at the same time, provide a platform for further research.

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3.5 Permeability of the city–Physical barriers of and in urban green spaces in the city of Halle, Germany [single-city paper]

Barber, A., Haase, D., & Wolff, M. (2021). Permeability of the city–Physical barriers of and in urban green spaces in the city of Halle, Germany. Ecological Indicators, 125, 107555.

Urban green spaces (UGS) play a vital role in cities by offering essential ecosystem services that contribute to human health and well-being. They provide fresh and cooling air, aesthetic beauty, and opportunities for physical activities. However, realizing these positive effects depends on citizens having access to UGS. Unfortunately, numerous complex barriers can limit accessibility to green-blue infrastructure (GBI) and the associated benefits. The study by Barber et al. (2021) aimed to quantify and visualize the physical barriers that impede access to public and semi-public UGS in Halle, Germany, focusing on three spatial dimensions related to UGS. Within each dimension, they defined three indicator classes that serve as proxies for different aspects of accessibility: "inside," "boundary," and "outside." They computed a barrier index for all public and semi-public UGS in the city, which aggregates the ratings for each indicator class. This comprehensive assessment resulted in a final barrier index that effectively illustrated the full spectrum of physical barriers within, around, and leading to UGS areas.

Their findings revealed the extent to which UGS accessibility may be constrained in Halle. Notably, the barrier index was highest for inside barriers, indicating that accessibility faces the greatest challenges within UGS areas across the city. Conversely, the inner city displayed relatively low barrier indices, highlighting better accessibility to UGS in these districts. Additionally, semi-public UGS, such as gardens and cemeteries, exhibited more substantial physical barriers compared to their public counterparts.

By linking the barrier index to current urban planning efforts and evaluating how the indicators defined in this study align with planning documents aimed at enhancing accessibility, the research offers a valuable tool for identifying potential spatial planning measures that can effectively reduce physical barriers to UGS. This approach supports the broader goal of improving UGS accessibility, thereby enhancing the quality of urban life in Halle.

In summary, the paper provides a complementary assessment of physical barriers using a multi-layer approach. The study quantifies barriers in the city case study of Halle, Germany focusing on three spatial dimensions using a rich set of indicators and a deduced barrier index for all UGS. This index allows to estimate the accessibility for public and semi-public spaces like gardens or cemeteries, being of high relevance for the current urban planning in the city.

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3.6 Planning to Practice: impacts of large-scale and rapid urban afforestation on greenspace patterns in the Beijing Plain Area [Single-City Paper]

Jin, J., Sheppard, S.R., Jia, B. and Wang, C., 2021. Planning to practice: impacts of large-scale and rapid urban afforestation on greenspace patterns in the Beijing plain area. *Forests*, 12(3), p.316.

In 2012, Beijing embarked on its most extensive afforestation program to date, aiming to create two green rings, three greenbelts, nine green wedges, and numerous green corridors. Over the span of four years, from 2012 to 2015, this ambitious initiative led to the planting of over 54 million trees across 70,711 hectares of land. Despite the notable expansion of green spaces in the plain areas, there was a lack of comprehensive understanding regarding the tangible outcomes in terms of changes in green space patterns during and after this rapid afforestation effort. Consequently, before delving into a deeper evaluation of ecosystem services and the associated costs and benefits, it was imperative to assess the spatial-temporal changes that occurred during the implementation of afforestation.

The research affirmed that large-scale and swift afforestation significantly enhances UGS by converting cropland and other types of land, including built-up and impervious areas, into forests and urban parks. Inner-city afforestation further accelerated the transformation of small green spaces into larger, contiguous patches, potentially bolstering urban resilience and conservation efforts. After afforestation, there was greater aggregation of forest patches despite the overall fragmentation of the landscape, which promises benefits for urban biodiversity and human well-being. Nevertheless, challenges persist in terms of selecting the allocation of afforestation sites and managing the substantial transition from cropland to forest, which necessitates future optimization and conservation strategies for the Beijing Plain Afforestation Program (BPAP).

Overall, the research underscores the utility of spatially explicit data and analysis in evaluating the immediate outcomes, both specific and cumulative, of ongoing afforestation programs. Building upon this research, future endeavours should prioritize a comprehensive assessment of the social, ecological, and economic impacts within newly afforested areas. A more focused examination of the specific ecosystem services provided by afforestation is also warranted as is comparative research across various afforestation programs. This is essential for elucidating the real-world efficiency of inner-city afforestation, encompassing planning and implementation stages.

4 THE CITY AND TREES: HOW SOCIAL AND ECOLOGICAL DYNAMICS MIRROR EACH OTHER IN THE URBAN SPACE

The urban forest does not exist in isolation; its growth, management, and utilization are influenced by broader urban dynamics that extend beyond the forest itself. It's essential to recognize that urban forests encompass more than just a collection of trees; they are integral components of a larger socio-ecological landscape that involves people, institutions, and infrastructures. This observation calls for a multidisciplinary approach for studying urban forest and its integration into broader morphological, socio-demographic, and environmental settings and dynamics. Understanding the dynamics that

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frame and shape the realisation of UF-NBS, requires going beyond urban forestry into other disciplines, seeking for a holistic analysis of the issues at stake, or simply looking at the interface between urban forestry and other themes such as demography, housing, or mobility.

In this chapter, we engage with questions through four articles which are either published or under review. First, a conceptual paper illustrates the characteristics of a traits framework, as way to make sense of the complex relations between the urban and the silvan component of the urban forest, by understanding social-ecological patterns, dynamics, interactions, and tipping points. Secondly, we look into urban population density and its complex relation with sustainability objectives, involving questions related to biodiversity loss within urban spaces vs. urbanisation of land at the urban edges. In the last two papers we engage in a reflection on the links and tensions between mobility and urban greening priority. We do so by looking first at the planning history of Brussels' Bois-de-la-Cambre Park and at differing preference of citizens today for the park use, and then at a research-by-design driven process to conceptualise and articulate the Park Street. None of the papers in this chapter are comparisons of the CLEARING HOUSE case study cities but the content is relevant nonetheless as the themes were part of reflections across the case study cities (this is probably more visible in the more policy-orientated deliverables of the project).

4.1 What are the traits of a social-ecological system: Towards a framework in support of urban sustainability. [Conceptual paper]

Andersson, E., Haase, D., Anderson, P., Cortinovis, C., Goodness, J., Kendal, D., Lausch, A., McPhearson T., Sikorska D. & Wellmann, T. (2021). What are the traits of a social-ecological system: Towards a framework in support of urban sustainability. npj *Urban Sustainability*, 1(1), 1-8.

In this conceptual paper, the potential of a **traits framework** for understanding social-ecological patterns, dynamics, interactions, and tipping points in complex urban systems is explored. In doing so, what kind of framing and research is required to link the sensitivity of a given environmental entity to different globally relevant pressures is discussed. In addition, how to connect to human appraisal and diverse bio-cultural sense-making, and under what conditions this new approach may trigger, inform, and support decision-making in land management at different scales are considered.

Traits are attributes that pertain to biophysical limitations, species' pressure, ecological functionality, and interactions. They have come to the forefront of many discussions and debates about ecosystem dynamics and, with a slight time lag, social-ecological systems. We see traits as a nexus where different theories and conceptualizations about social-ecological systems can connect, intertwine, and comprehensively allow us to assess the current state of a system—and even more importantly, evaluate the implications of change. In this context, the potential of a traits framework is to advance our understanding of patterns, dynamics, interactions, and tipping points within and across complex social-ecological systems.

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There are three dimensions of a social-ecological traits framework for understanding and governing urban systems.

The first dimension focuses on observable characteristics within the urban environment, encompassing attributes of humans and other coexisting species. These attributes exhibit diverse reactions to external pressures and selective forces, ultimately leading to functional outcomes and significant alterations in the nature of urban social-ecological systems. Trait-based methodologies have traditionally been employed for descriptive purposes, facilitating broader global comparisons that transcend the limitations posed by regional taxonomic diversity. For this primary dimension, the utilization of trait databases, traditional field inventories, experimental data, remote sensing information, and GIS-based resources proves essential. Over the past two decades, there have been notable advancements in the quest to establish a comprehensive library of trait responses and effects, particularly within the fields of ecology and remote sensing. However, it's worth noting that these recent breakthroughs in remote sensing studies still struggle to gain widespread recognition within the domains of urban planning and policy decision-making.

The second dimension operates through feedback loops among the resulting effects, individual and collective perceptions, and decision-making processes. In this context, traits serve as an interdisciplinary bridge. The literature that explicitly employs the term "traits" tends to concentrate on soil, geodiversity, plant, and community trait profiles, which emerge as a consequence of social-ecological selection driven by environmental conditions, species interactions, human preferences, management practices, and more. In this paper, we propose viewing the environment, as characterized by traits, as a boundary object (see Box 1, page 14 of the article). This perspective allows for a multitude of perspectives, disciplinary connections, engagements, and perceptions, effectively addressing the complexity of social-ecological systems. This approach broadens the spectrum of functions used to describe a system and diversifies the types of traits needed to capture them. Traits, then, can be seen as a formative force influencing human well-being and world views, giving shape to ecological systems, and linked human affordances (through, e.g., shade and sensory stimuli), and social systems by shaping the context of human activities and experiences.

Finally, the third dimension encompasses urban ecosystem planning and management integrated into governance processes and tools. The fundamental aim of the traits concept, as presented here, is to construct an ontologically inclusive framework capable of addressing both the resilience of ecological functions and the experiential and relational aspects of human interactions with nature. Practically, this would be highly pertinent across a broad spectrum of decision-making contexts, particularly in urban planning. Clearly visible and easy-to-map traits are well-suited as indicators to describe the state of urban landscapes relevant for biodiversity and society alike. In this context, indicator traits must possess qualities of robustness, ease of measurement, cost-effectiveness in assessment, and a demonstrable causal link to relevant social-ecological processes and patterns (such as ecosystem services related to recreation, cooling, or food provision). The selection of traits can significantly contribute to the planning, design, and subsequent evaluation of the functionality of high-biodiversity green spaces. Moreover, it enables trait-informed assessments of "performance," for instance, in

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ecologically protected areas. From this perspective, we see the traits framework as a potential catalyst for fostering a shift towards more adaptable and efficient planning approaches, better suited to confront the contemporary challenges faced by urban environments. This shift aims to advance the well-being, sustainability, and resilience of both present and future cities.

Traits that are easily comprehensible and directly related to ecosystem services like cooling and fresh air can serve as an entry point for raising nature awareness and, subsequently, enhancing ecological knowledge. This holds true for decision-making processes at both the individual citizen and societal levels. However, for traits to effectively function as indicators of environmental changes at global, regional, or local scales, it is an imperative to recognize the diversity within urban society. This diversity spans characteristics such as cultural backgrounds, physical mobility, gender, age, levels of formal or informal education, access to information and communication, purchasing power, and political influence. All of these factors significantly influence the needs, preferences, and values of individuals and groups, as well as how each interprets the relationship between humanity and nature. Only by taking these multifaceted factors into account can we effectively plan for spatial and temporal diversity in traits across an urban landscape. Such an inclusive approach has the potential to create urban systems that embrace a wide range of benefits, serving both the well-being of people and the preservation of biodiversity.

4.2 Higher immigration and lower land take rates are driving a new densification wave in European cities [comparative paper]

Cortinovis, C., Geneletti, D., & Haase, D. (2022). Higher immigration and lower land take rates are driving a new densification wave in European cities. npj *Urban Sustainability*, 2(1), 1-14.

This paper explores urban densification and de-densification trends at the European level. The physical expansion of cities threatens biodiversity, causes the loss of agricultural land, and alters climate at multiple scales. Higher density means that less space is needed to accommodate the same population, hence more land is saved for other uses.

As urbanization advances through both an increase in urban population and the expansion of urban land, density—typically defined as the relationship between population and occupied area—stands out as a key indicator of its efficiency. As an increasing body of scientific evidence highlights a decline in density in numerous urban areas globally, policies at various levels are advocating for densification as a means to attain a more sustainable form of urban development.

The same density trends can hide different urban development patterns. De-densification in growing cities, i.e. where population increases, can be considered an indicator of suburbanization or sprawl, but in shrinking cities it may either simply indicate population loss, or conceal a decoupling between loss of population and expansion of residential areas. On the other hand, although uncommon, large-scale demolitions can achieve densification even in the context of stable or shrinking population. Different urban development trajectories produce different impacts on both human wellbeing and

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the urban environment. To correctly interpret density trends as a basis for policymaking, it is therefore an imperative to consider the evolution of both their components, namely population change and land use change.

In this context, the objective of this study was to scrutinize the recent density patterns in European cities. This involved examining the fundamental trends in population and residential area and identifying instances of transition from de-densification to densification, if any. Specifically, a comparative analysis of urban transformations in terms of residential density, population, and residential area from 2006 to 2018 was conducted. To achieve this, the research team integrated high-resolution land use and cover data from the Urban Atlas with demographic information sourced from Eurostat and national statistical offices.

The study encompasses a sample of 331 EU cities with populations exceeding 50,000. The diverse range of local geographic, climatic, historical, and socio-economic conditions, coupled with a multitude of planning approaches and policies, positions Europe as an exceptional vantage point for analysing the multifaceted nature of urban development. Despite this diversity, the European Union provides a degree of coordination in crucial policy domains, including spatial development. Notably pertinent to the discussion of density is the 'no net land take' initiative introduced by the European Commission in 2011. This initiative aims to achieve a balance where there is no net increase in non-urban land use by the year 2050.

The analysis revealed a notable shift in the recent urban development of European cities, transitioning from diffuse de-densification to a prevailing trend of densification. Between 2006 and 2012, residential density experienced a decline in most European cities. However, over the subsequent six years, the majority of cities demonstrated an increase in density, with one-quarter of the sample making a shift from de-densification to densification. Two primary trends drove this shift. Firstly, there was a more dispersed pattern of population growth, with shrinkage confined to specific geographic areas, particularly in eastern cities and the Iberian Peninsula. Notably, an inversion of population dynamics was observed in the majority of cities in Italy and Germany, as well as in certain cities in France and Czechia. Secondly, there was a significant reduction in land allocated for residential use between the two periods, observed in over two-thirds of the cities in the sample. The findings for the initial period align with several studies demonstrating a consistent decline in density over recent decades. This trend is not limited to Europe, but also extends to other 'land-rich developed countries' such as the USA and Canada, as well as fast-developing economies like India and China. Given this context, the predominant shift towards (re-)densification in European cities in the most recent years stands out as a noteworthy development.

These cases serve as emblematic examples of how trends at various levels, be it national, continental, or even global, can significantly influence the trajectories of urban development. National policies also play a substantial role in shaping these outcomes. For instance, explicit planning policies that advocate for densification, as seen in the Nordic countries, the UK, and the Netherlands, have had a discernible impact. Social and family policies, as observed in France, present another notable factor. France stands as a unique case among European countries, where the population trends of most cities are driven by

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natural growth. In our sample, seven large and medium-sized French cities transitioned from de-densification to densification, propelled by an accelerated rate of natural growth despite significant outmigration—a distinctive trajectory not observed elsewhere. Since the conclusion of the Second World War, a wide array of active family policies has contributed to the elevated fertility rates that underpin these trends. While not all of these national specificities are novel, some recent ones have, to a certain extent, superseded established regional patterns of urban development, including the traditional similarities found in southern (including Spanish and Italian) cities.

Given the potential implications of the findings for sustainability policies, the recent surge in densification offers an opportunity to bolster the execution of the 'no net land take' strategy. This, in turn, could help alleviate the pressures of urbanization on the environment in general and on the urban forest in particular.

4.3 Between green spaces and mobility: exploring diverging perspectives on the admission of motorised traffic in the Bois de la Cambre (Brussels, Belgium) [single city paper]

da Schio N, Pelgrims C., Vandenbroucke L. Cincinnato S. (in press), Between liveability and accessibility in Brussels' Bois de la Cambre, *Brussels Studies*

This paper examines the controversy surrounding the set-up of large urban park in Brussels, namely whether to allow or not motorised traffic through the park. The case, which is explored through historical analysis, speaks of conflicting visions regarding the use of the urban forest, i.e., to realise urban accessibility **or** a place for leisure.

The paper shows how the organization of the Bois de la Cambre (a park in Brussels, Belgium) has been a source of considerable controversy since its inception. During the 19th century, it served as a testing ground for innovative urban traffic separation concepts, which segregated horseback riders from pedestrians and horse-drawn traffic. As the bicycle gained popularity later in the same century, adjustments were made to the park's pathways to accommodate the growing number of cyclists. The emergence of the automobile led to further modifications and transformed the park's network of leisurely promenades into high-speed motorways. Post-World War II, debates shifted from integrating cyclists and motorists to discussions about modernizing the road network. These debates pitted proponents of converting park roads and sections of the Sonian Forest into urban motorways against those advocating for more space-efficient and leisure-oriented scenic routes.

The most recent debate regarding the optimal use of the park began during the initial COVID-19-related lockdown. The need for physical distancing and the surge in park and green space visits, driven by the limited availability of other leisure activities during the pandemic, underscored the importance of open spaces in addressing the challenges posed by the health crisis. Furthermore, the first lockdown

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resulted in a significant reduction in traffic volumes due to widespread telecommuting. Against this backdrop, the City of Brussels made the decision in March 2020 to redirect motorized traffic away from the park, recognizing the heightened demand for open, accessible spaces and the changing dynamics of urban mobility.

After tracing the history of the planning and design of the park, we examined individual preferences in relation to different setups of the Bois de la Cambre, through a survey of citizens. We analysed the profiles of groups with different preferences in relation to their use of the park, their socio-demographic situation, the places where they live and work, their mobility practices and access to green spaces.

This case study illustrates the tensions that can operate in (peri)urban green spaces between geographical accessibility and liveability. While conflicting visions for the park emerged again in 2020, they were not a new phenomenon and have characterized the history of the parc. Every redevelopment proposal made since 1966 has induced strong reactions, either positive from those who see their opportunities expanded, or negative from those who feel them to be more constrained. The last reorganisation of car traffic in the park, proposed in 2020, is in line with the evolution of recent decades, even if the way in which motorised traffic has been problematized over time has changed. The archival analysis suggests that the adaptations that were made over time to the layout of the park reflect changing leisure and mobility practices and the evolution of broader ways of life, rather than being a consequence of an explicit project for the park. However, this laissez-faire attitude resulted in an incremental transformation of the main parkways into major roads, perceived by some as a socio-environmental problem and by others as a necessity vis-à-vis the lack of alternative access routes to the city from the southern periphery.

The survey which we performed shows that the different claims that are made today regarding the use of the park are strongly connected to residential location, habitual modes of transport and the use of and access to green spaces. These practices reflect divergent lifestyles that are inspired by dominant imaginaries of mobility and the city, and that evolve slowly. In that sense, our analysis stresses the need to work both on the elaboration of concrete alternatives — concerning more sustainable transport options, the affordability of urban residential locations, and/or the geographic relation between places of residence and places of work — and on the construction of new urban and mobility imaginaries.

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4.4 The park street: striking the balance between mobility, biodiversity, and permanence functions of public space (Brussels, Belgium) [single-city paper]

da Schio N. & De Lestrange R. (under review) *The park street: striking the balance between mobility, biodiversity, and permanence functions of public space* (Brussels, Belgium)

This paper continues the exploration of the links between mobility and urban green in Brussels, but does so from a very different angle i.e., exploring the possibility of combining urban greening and urban mobility functions in the urban street by mobilising and developing **the concept of park street.**

This concept, rooted in the historical tradition of landscape urbanism, is experiencing a resurgence in contemporary urban planning. This project defined the Park Street as a green infrastructure that serves as a multifunctional space for permanence, vegetation, rainwater management, and active mobility. Typically implemented at the neighbourhood level, the Park Street is integral to a comprehensive and multi-scalar approach to landscape and urban design, with the aim of creating biodiverse, sponge-like, cool, liveable, inclusive, and tranquil urban environments. While acknowledging the technical and mechanistic nature of streets as infrastructure, the Park Street approach prioritizes their role as common spaces that welcome both human and non-human inhabitants. The research took an exploratory approach and conducted a design experiment involving the conceptualization and process of implementing Park Streets. This endeavour yielded visual representations of three Park Street scenarios and generated several insights arising from the exchange, creation, and reflection processes.

Methodologically, the research drew inspiration from research-by-design practices, involving a process of discussion among stakeholders, design, and feedback. Employing a multi-actor framework of reflection and maintaining an exploratory and non-prescriptive stance, the process generated imaginative solutions that were both concrete and generalizable, rooted yet adaptable to different contexts. The decision to limit the design work to sketches (rather than detailed plans) ensured that these ideas could be adopted and customized by those responsible for their implementation. While this approach is common in research-by-design endeavours, it is worth noting that the article did not comprehensively explore all possible solutions to the given problem. Furthermore, a tension arose between the aspiration to pursue pragmatic feasibility without disrupting existing practices and conditions and the desire to pursue what would be most effective in ensuring healthy ecosystems that enhance the resilience and liveability of the city.

From an environmental perspective, the article shows how the park street systematically extends the traditional longitudinal ecological connectivity along streets to include transversal connections through building blocks. This increased permeability, blurred the boundaries between built and natural spaces, and pointed towards the development of a biophilic city. These proposals called for coherence, integration, and dialogue between local and supra-local, private, and public, urban, and environmental considerations, serving as catalysts for integrated urban design and management.

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However, the tension between objectives of ecological connectivity and the provision of "natural" leisure spaces remained unresolved.

From a mobility standpoint, the reflections presented in the research deconstruct and redefine the hierarchy of transport modes. Local officials responsible for mobility recognized how vegetation could calm traffic through both its physical presence, which encourages careful driving, and its sensory presence, which has a soothing effect on people's behaviour. Nevertheless, significant trade-offs persist. In an environment dominated by infrastructure optimized for motorized mobility, implementing Park Streets inevitably meant reducing the space allocated to such infrastructure. This proved challenging for shopkeepers and certain age groups, particularly in areas with limited public transport access. These reactions underscore the need for a broader approach to post-car urban accessibility in Park Street implementation.

The process of research by design, adopted in the research, also highlighted governance and urban space management issues. Park Streets could be integrated into policies for protecting natural habitats and wildlife as well as policies aimed at creating pleasant and appealing living environments. As streets become supplementary to parks and green spaces in providing various ecosystem-based services, their management becomes more complex, blurring professional boundaries and institutional responsibilities. This observation carries significant implications for urban governance at various levels of public space management.

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5 CONCLUSION

This report (D2.2) has synthesised a range of published papers and reports by the CLEARING HOUSE consortium to understand and compare the implementation of UF-NBS in European and Chinese cities. We conclude with a summary of **key findings** and **recommendations** for each thematic chapter (that we found are important for implementing UF-NBS) before considering the **similarities and differences between UF-NBS in Europe and China** (Section 5.4).

5.1 Key Findings - Governance and Management of UF-NBS (Chapter 2)

Comprehensive policy frameworks: Effective governance begins with the establishment of comprehensive policy frameworks that recognize the importance of UF-NBS. These policies encompass tree protection, planting, and maintenance. They often include tree ordinances, master plans, and land use regulations that ensure the integration of green spaces into urban development.

Integration with urban planning and design: We find that it is important to integrate tree planting and maintenance into urban planning and design processes, for example, considerations about tree species selection, appropriate planting locations, and infrastructure compatibility to ensure the long-term health and resilience of urban trees.

Data, monitoring and evaluation: Accurate data, monitoring and evaluation systems are vital to assess the health of urban forests, track changes over time, gauge effectiveness, make informed decisions and adapt strategies as necessary. Remote sensing, GIS technology, and citizen science programs can provide valuable insights into tree canopy cover, species diversity, and urban heat island effects. Metrics such as tree survival rates, air quality improvements, and community satisfaction can inform future governance decisions.

Diversity in participation: Governance of UF-NBS involves engaging a diverse range of stakeholders, including government agencies, non-profit organizations, community groups, and the private sector. Collaboration, partnerships and co-production are essential for pooling resources, expertise, and support for UF-NBS initiatives.

Fragmentation of green spaces: One of the key challenges faced by all cities is the fragmentation of green spaces, particularly in the urban core. All CLEARING HOUSE cities have identified the need to create more accessible green space and improve the quality and distribution of green space to ensure equitable access for all citizens.

Meeting multifunctional demands on green space: Another common challenge identified by the CLEARING HOUSE case study cities is the need to meet the multifunctional demands on urban green space, such as recreation, biodiversity protection, air quality, and climate change adaptation. These demands, however, can have considerable synergies. For example, cities need to balance the need for green spaces to mitigate the urban heat island effect while also providing recreational opportunities for citizens.

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Varied public engagement efforts (country/city): Within CLEARING HOUSE, a notable contrast among the case study cities lies in the extent of public engagement in policy making and citizen science endeavours. In certain cities like Brussels and Leipzig, citizen science projects have gained traction, with active support from public authorities and NGOs. Conversely, in Krakow and Gelsenkirchen, citizen science approaches are still nascent, necessitating more collaborative efforts to involve the public in evaluating and managing UF-NBS. In China, public engagement in policy making is notably lacking. However, there are growing efforts to raise awareness of UF-NBS and the wider ecological significance to society via science education and digital technologies. This is alongside very successful campaigning to encourage the voluntary planting of trees by citizens.

Lack of (or low) finances dedicated to UF-NBS: While UF-NBS efforts are undeniably desirable in cities, sustaining the success of such programmes depends on securing sufficient financial resources. Despite the unique contexts of each city case study, several shared challenges emerged. These include how municipal budgets are allocated, which typically must be divided between implementing new UF-NBS projects and maintaining existing ones. The initiation of new UF-NBS programmes usually requires public and/or private sector funding, alongside the necessity of available urban space. Notably, UF-NBS projects do not primarily seek profits, as investors as motivated by broader environmental and societal benefits rather than financial returns. Given that cost-effectiveness is not a main driver for new UF-NBS initiatives, the availability of suitable urban space becomes a crucial factor, emphasizing the importance of city green policies. Unfortunately, the allocation of municipal budgets for UF-NBS maintenance often falls short of actual requirements, highlighting the pressing need for increased investment in maintenance.

5.1.1 Governance and Management: Key Recommendations

Environmental justice: To ensure the benefits of urban forestry are distributed equitably, governance efforts should prioritize marginalized and underserved communities. Strategies for achieving this include equitable tree distribution and community involvement in decision-making.

Prioritise climate resilience: Given the increasing impact of climate change, UF-NBS governance should prioritize climate resilience. This may involve selecting tree species that are better adapted to changing conditions, implementing irrigation systems during droughts, and developing emergency response plans for extreme weather events.

Engage in citizen science and public participation: Citizen science and public participation approaches (e.g. co-production) can help identify and inform the decision-making and also help prioritising these (sometimes) competing demands from urban forests.

Ensure investment is increased: Sustainable finance is required to initiate, manage and importantly, maintain UF-NBS initiatives. When seeking funding, it is important to identify suitable urban space and its availability alongside highlighting the societal and ecological benefits of UF-NBS.

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5.2 Key Findings – The Geography of UF-NBS: exploring questions of connectivity and accessibility (Chapter 3)

The importance of green and blue spaces in urban areas: Our research emphasises the importance of green and blue spaces in urban areas (e.g. forests, lakes, parks and gardens) because they provide various ecosystem services and socio-economic benefits such as physical activity, recreation, social interaction, health and well-being.

Connectivity and accessibility: Green and blue spaces in cities faces challenges such as urban expansion and population growth which increases pressure on these spaces and affects accessibility and connectivity. Therefore, it is important to understand the differences in accessibility and connectivity among different cities. We found that spatial network analysis can help measure green and blue area accessibility, with different perspectives such as Buffer Analysis, Network Analysis, and Distance-Decay Analysis, and the development of new indicators for characterising connecting edges.

The role of brownfields: Brownfield land, previously developed land that may be underutilised or contaminated, can play a significant role in enhancing the connectivity of green and blue spaces in cities. Revitalising brownfield through re-naturing requires support and evidence as there are competing pressures whereby cities are simultaneously aiming for densification *and* the maintenance or development of green spaces as the example of Leipzig in Germany demonstrated.

Barriers to accessing green and blue space: It is important to consider barriers to accessing urban green spaces and their multifaceted nature, including physical, personal, and institutional barriers, to improve the realisation of recreational benefits from these spaces.

The impact of large-scale and rapid urban afforestation: As the case study of Beijing, China demonstrated, it is important to have a comprehensive understanding of the impact of rapid afforestation in terms of the ecosystem services, associated costs and benefits and the spatial and temporal changes during implementation.

5.2.1 The Geography of UF-NBS: Key Recommendations

Consider the interconnectedness of Ecosystem Services: Urban planners and governments should recognise that urban green and blue spaces are interconnected and provide a wide array of ecosystem services and socio-economic advantages. When planning for urban development, they should consider how changes in one area can impact the accessibility and functionality of these spaces in another. This interconnectedness should be a central consideration in urban planning.

Promote accessibility to green and blue spaces: In rapidly growing cities, accessibility to green and blue spaces is crucial for residents' health and well-being. Designing and maintaining green spaces that are accessible to everyone should be a priority. This can also include creating walkable environments and efficient public transport systems to improve connections to green and blue spaces.

Environmental justice: The fairness of flows of people in, out, and around green and blue spaces should be assessed. It is important to ensure that the benefits of these spaces are distributed equitably

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among the population. Civic society can play a role in advocating for accessible green spaces for all residents, especially those in underserved communities.

Consider the role of brownfields: Brownfields, when revitalised and integrated into green infrastructure, can play a significant role in enhancing the connectivity of urban tree systems.

Understand multidimensional barriers: Barriers to accessing urban green spaces go beyond physical aspects and can include personal and institutional factors. A conceptual framework that categorises barriers into physical, personal, and institutional dimensions should be used to enhance the understanding of why individuals might not utilise urban green spaces. Civic society, along with planners and governments, should work to identify and address these barriers to ensure that green spaces are accessible to a broad range of individuals.

Monitor physical barriers: To improve the accessibility of urban green spaces, it is essential to quantify and visualize physical barriers within, around, and leading to these areas. Urban governments and planners should use this information to develop measures that reduce physical barriers and enhance the quality of urban life.

Evaluate large-Scale afforestation: Governments should consider the impact of large-scale afforestation efforts on urban green spaces. By assessing the spatial and temporal changes that occur during such programs, they can optimise the allocation of afforestation sites and manage the transition from cropland to forests to enhance urban resilience and conservation.

5.3 Key Findings – The City and Trees: how social and ecological dynamics mirror each other in urban space (Chapter 4)

Urban forests are complex socio-ecological systems: Urban forests are not isolated entities but are part of broader urban dynamics. They are shaped by various factors, including human activities, institutions, and infrastructure. Therefore, understanding UF-NBS requires a multidisciplinary approach and the integration of UF-NBS with other aspects of urban life, such as demography, housing, and mobility.

Importance of a traits framework: Section 4.1 (Andersson et al., 2021) introduces the concept of a "traits framework" to understand social-ecological patterns, dynamics, and interactions in complex urban systems. This framework focuses on observable characteristics within the urban environment and serves as an interdisciplinary bridge. It can help assess the state of urban landscapes relevant to biodiversity and society.

Shift towards urban densification: Section 4.2 (Cortinovis et al., 2022) discusses a shift from de-densification to densification in 331 European cities, with populations over 50,000. It highlights that higher population density can lead to more efficient land use, reducing the environmental impact of urban expansion. This trend is significant for sustainability policies and environmental preservation.

Controversy in urban park usage: Section 4.3 (da Schio et al., in press) examines the controversy surrounding the use of the Bois de la Cambre park in Brussels. It traces the historical evolution of the

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park's usage, from accommodating different modes of transportation to the recent decision to restrict motorized traffic. It shows how different visions of park use, including accessibility and leisure, can lead to conflicts.

The concept of Park Streets: Section 4.4 (da Schio and De Strange, under review) introduces the concept of "Park Streets" as a way to combine urban greening and urban mobility functions. These streets are designed as multifunctional spaces that promote vegetation, rainwater management, and active mobility. The approach emphasizes the need for a balance between ecological connectivity and leisure spaces.

Environmental and mobility implications: The research on Park Streets reveals that they extend ecological connectivity and blur the boundaries between built and natural spaces, contributing to the development of a biophilic city. However, implementing Park Streets can result in trade-offs, especially in areas dominated by motorised infrastructure, affecting shopkeepers and certain age groups.

5.3.1 The City and Trees: Key Recommendations

Multidisciplinary approach: Recognise that urban forests are part of a larger socio-ecological landscape, and implement a multidisciplinary approach that integrates urban forestry with other aspects of urban life, including demography, housing, and mobility.

Traits framework: Consider the use of a traits framework to understand social-ecological patterns, dynamics, interactions, and tipping points in complex urban systems. This framework can help assess the state of urban landscapes relevant to biodiversity and society.

Community involvement: Engage the community in decision-making processes related to urban forests and green spaces. Consider the preferences and values of diverse groups to plan for spatial and temporal diversity in urban landscapes.

Address controversies related to the usage of urban parks by engaging with the community and stakeholders. Understand the diverse visions of park use, such as accessibility and leisure, and work towards a balance that considers both aspects.

Park Streets concept: Explore the concept of "Park Streets" to combine urban greening and urban mobility functions. Design streets as multifunctional spaces that promote vegetation, rainwater management, and active mobility. Also, assess the mobility aspects and potential trade-offs with motorized infrastructure.

5.4 Key Findings – Comparing UF-NBS in Europe and China

We finish our report with some observations identified at a workshop held during the CLEARING HOUSE 4th General Assembly in Krakow, Poland on the 23 May 2023. The aim of the workshop was to **compare the differences and similarities between UF-NBS in Europe and China**. We find that the

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distinctions between UF-NBS in Europe and China are shaped by each region's unique socio-economic, environmental, and cultural contexts (Table 5. 1).

Table 5. 1 Comparison of UF-NBS in Europe and China

	Europe	China
Historical Context	European cities have a long history of urban forests and green spaces, often dating back centuries. These green areas have evolved over time and are deeply ingrained in European urban planning and culture.	In China, rapid urbanization over the last few decades has led to significant challenges in terms of UGS development. While traditional Chinese cities had gardens and parks, the modern concept of urban forests is relatively new and evolving.
Environmental Challenges	European cities face challenges related to climate change, such as increased heatwaves and shifting planting zones. UF-NBS are key solutions in mitigating and adapting to these issues.	Chinese cities often grapple with severe air pollution, and UF-NBS are seen as a critical tool for improving air quality, providing clean air to residents and mitigating heatwaves
Governance and Management	European UF-NBS often involves partnerships of public authorities, non-governmental organizations, and citizen engagement. Governance models vary widely across countries. Management is guided by sustainable forest practices.	Urban forest governance in China is typically more centralized, with local governments playing a prominent role in planning and management. However, there is growing interest in involving communities and citizens.
Cultural Ecosystem Services	European urban forests are often cherished for their cultural and recreational value. They serve as spaces for relaxation, leisure activities, and cultural events.	Chinese urban forests are gaining cultural significance as well, as they become more integrated into the lifestyle of urban residents, aligning with traditional values of harmony with nature and providing residents with spaces for relaxation and exercise. Traditional Chinese cultural values also play a role in shaping the design and use of urban forests.
Geography	European cities, generally less densely populated than many Chinese cities, can afford more extensive urban forests. These may cover large areas and include parks, woodlands, and green corridors.	Many Chinese cities are densely populated, leading to a higher demand for limited green space.
Multifunctionality	European urban forests often serve multiple purposes, including biodiversity conservation, climate	In China, urban forests are primarily employed as a response to severe air pollution and urbanization challenges.

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	change mitigation, and improving quality of life. They are integrated into urban planning as part of broader sustainability strategies.	Their main goal is to enhance air quality and provide green spaces for residents in rapidly expanding cities.
Tree Species Diversity	European urban forests often prioritize native and diverse tree species, focusing on ecological sustainability and biodiversity conservation. There are similarities in the selection of tree species between cities.	Chinese urban forests may have a mix of native and non-native species, with a growing emphasis on urban afforestation to combat air pollution and enhance urban aesthetics.

In conclusion, cities in Europe face challenges related to urban sprawl, loss of green space, and invasive species. Other climate challenges are adapting to shifting planting zones and addressing the impact of extreme weather events. Whereas, the primary challenge in China is combating severe air pollution and heatwaves. Urban forests are seen as part of a broader strategy, including afforestation and green infrastructure, to address this issue. There are opportunities, despite these considerable challenges, and in Europe these lie in sustainable forest management, climate adaptation such as climate-resilient tree species, and enhancing ecosystem services. In China, the rapid expansion of green infrastructure provides an opportunity for innovative UF-NBS design.

Both regions can learn from each other's experiences and best practices to continue improving the sustainability and resilience of UF-NBS in the face of ongoing urbanisation and environmental challenges. Europe's long history of urban forests, parks and green spaces and achievements in urban biodiversity conservation through initiatives like green corridors and urban nature reserves are areas where China can learn from these practices to enhance biodiversity in their cities. Europe has well established policies and practices for urban forestry and green infrastructure and there is a strong tradition of involving citizens in urban forestry – these can provide useful models and/or templates for China to adopt. Rapid urbanisation in China has led to innovative approaches such as eco-cities which European cities can learn from. China has a rich history of traditional knowledge related to forests and nature and Europe can benefit from understanding these ancients practices. Europe has experience of urban forests as a means of climate mitigation and adaptation which China can learn from to combat air pollutions, urban heat islands etc. Finally, both regions can benefit from continued collaboration on research, knowledge sharing and best practices in UF-NBS.

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BIBLIOGRAPHY

Andersson, E., Haase, D., Anderson, P., Cortinovis, C., Goodness, J., Kendal, D., Lausch, A., McPhearson T., Sikorska D. & Wellmann, T. (2021). What are the traits of a social-ecological system: Towards a framework in support of urban sustainability. npj *Urban Sustainability*, 1(1), 1-8.

Barber, A., Haase, D., & Wolff, M. (2021). Permeability of the city–Physical barriers of and in UGS in the city of Halle, Germany. *Ecological Indicators*, 125, 107555.

Biaz, L., (2022) *Sustainable funding mechanisms for UF-NBS and cost-effectiveness*. Deliverable from Work Package 2, Task 2.2, Workstream 3. H2020 project CLEARING HOUSE, agreement no. 821242.

Cortinovis, C., Geneletti, D., & Haase, D. (2022). Higher immigration and lower land take rates are driving a new densification wave in European cities. npj *Urban Sustainability*, 2(1), 1-14.

da Schio Nicola, Baró Francesc, Basnou Corina, Bergier Tomasz, Cid Espinach Laura, Fransen Koos, Haase Dagmar, Mielczarek Łukasz, Nesselhauf Georg, Roitsch Dennis, Rudgalwis Norman, Scheuer Sebastian, Van Heur Bas, Vidal Casanovas Eugènia, Wolff Manuel (2021) *Report on the exploratory analysis of all the case studies* (D2.1). H2020 project CLEARING HOUSE, agreement no. 821242.

da Schio, N. (2022) *Detailed plan for the comparative analysis of the case studies (M2.4)*. H2020 project CLEARING HOUSE, agreement no. 821242.

da Schio N. & De Lestrange R. (under review) *The park street: striking the balance between mobility, biodiversity, and permanence functions of public space* (Brussels, Belgium)

da Schio N, Pelgrims C., Vandenbroucke L. Cincinnato S. (in press), *Between liveability and accessibility in Brussels'* Bois de la Cambre, Brussels Studies

Davies, C., Lafortezza, R., DeBellis, Y., Jin, J., Haase, D., Kronenberg, J., Roitsch, D., De Vreese, R., Krajter-Ostoić, S. (2020) *Analysing governance, institutional and economic frameworks for Urban Forests as Nature-Based Solutions (M1.6)*. H2020 project CLEARING HOUSE, agreement no. 821242.

DeBellis, Y., Lafortezza, R., Davies, C., Jin, J., Haase, D., Kronenberg, J., Roitsch, D., et al. (2020). *Reviewing the knowledge on the importance of UF-NBS for resilient cities* (D1.2). H2020 project CLEARING HOUSE, agreement no. 821242.

De Vreese, R. (2021) *Workshop to discuss finding from exploratory analysis conducted* (M2.3). H2020 project CLEARING HOUSE, agreement no. 821242.

De Vreese, R., Malandrino, C., Schante, J., Fu, W., Jin, J. and Wang, C. (2021) *Local co-design workshops sysnthesis report* (D3.2)). H2020 project CLEARING HOUSE, agreement no. 821242.

Dobbs, C., Kendal, D., & Nitschke, C. R. (2014). Multiple ecosystem services and disservices of the urban forest establishing their connections with landscape structure and sociodemographics. *Ecological Indicators*, 43, 44–55.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 821242 and the National Key R&D Programme of China under grant No 2021YEF0193200. The content of this deliverable does not reflect the official opinion of the European Union. Responsibility for the information and views expressed lies entirely with the author(s).

Dorst, H., Van der Jagt, A., Raven, R. and Runhaar, H., 2019. Urban greening through nature-based solutions–Key characteristics of an emerging concept. *Sustainable Cities and Society*, *49*, p.101620.

Fu W., Maurice S., Schanté J., Malandrino C., Jin J. & De Vreese, R. (2020). D3.1 *Guidance document for local co-design and co-learning workshops*. H2020 project no. 821242.

Gamfeldt, L., Snall, T., Bagchi, R., Jonsson, M., Gustafsson, L., Kjellander, P., Bengtsson, J. (2013). Higher levels of multiple ecosystem services are found in forests with more tree species. *Nature Communications*, 4, 1340.

Haase, D., de Schio, N. Davies, C., Jin, J., Basnou, C., Tyrväinen, L., Wolff, M., Lafortezza, R., De Vreese, R., DeBellis, Y., Scheuer, S., Chen, W., Schante, J., Bergier, T., Winkel, G., OTHERS. (2021) *Development of an Analytical Framework for the CLEARING HOUSE case study research* (D1.6). H2020 project CLEARING HOUSE, agreement no. 821242.

Hansen, R., & Pauleit, S. (2014). From multifunctionality to multiple ecosystem services? A conceptual framework for multifunctionality in green infrastructure planning for urban areas. *AMBIO*, 43(4), 516–529.

Jin, J., Sheppard, S., Jia, B. and Wang, C. (2021) Planning to practice: impacts of large-scale and rapid afforestation on greenspace patterns in the Beijing Plain Area, *Forests* 12 (3): 316

Jonsson, M., Bengtsson, J., Moen, J., Gamfeldt, L., & Snall, T. (2020). Stand age and climate influence forest ecosystem service delivery and multifunctionality. *Environmental Research Letters*, 15(9), 0940a8.

Manning, P., van der Plas, F., Soliveres, S., Allan, E., Maestre, F. T., Mace, G., Fischer, M. (2018). Redefining ecosystem multifunctionality. *Nature Ecology & Evolution*, 2(3), 427–436.

Mishra, H. and Tyrväinen, L. (2023) *Mapping the potential of the citizen science approaches for the assessment of UF-NBS trait perception and CES in five European cities*, Report by the National Resources Institute, Finland, LUKE for D2.2, CLEARING HOUSE.

Mitchell, M.G. and Devisscher, T., 2022. Strong relationships between urbanization, landscape structure, and ecosystem service multifunctionality in urban forest fragments. *Landscape and Urban Planning*, *228*, p.104548.

Pickard, B. R., Van Berkel, D., Petrasova, A., & Meentemeyer, R. K. (2017). Forecasts of urbanization scenarios reveal trade-offs between landscape change and ecosystem services. *Landscape Ecology*, 32(3), 617–634.

Roitsch, D., Davies, C., Konczal, A., Jin, J., Basnou, C., Kronenberg, J., Krajter Ostoić, S., et al. (2021). *Governance, institutional and economic frameworks for Urban Forests as Nature-Based Solutions (UF-NBS)* (D1.4). H2020 project CLEARING HOUSE, agreement no. 821242.

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Roitsch, D., da Schio, N., Krajter Ostoić, S., Zivojinovic, I., Vuletić, D., Armstrong, A., Czaplarska, A., Baró, F., Whitehead, I., Buiis, A. and De Vreese, R. (submitted in August 2023) Co-production of urban forests as nature-based solutions: motivations and lessons-learnt from public officials, *Environmental Science and Policy*

Scheuer, S., da Schio, N., Basnou, C., Chen, W. Y., Davies, C., De Vreese, R., Debellis, Y., Fransen, K., Haase, D., Jin, J. E., Lafortezza, R., Tyrväinen, L., Winkel, G. (2020). *Screening tool for the guidance of the exploratory case study analysis* (D1.5). H2020 project CLEARING HOUSE, agreement no. 821242.

Scheuer, S., Jache, S., Wellmann, T., Wolff, M., & Haase, D. (2021). *Outlining a semantics-based Sino-European UF-NBS typology* (Deliverable 1.1). H2020 project CLEARING HOUSE, grant no. 821242.

Scheuer, S., Wolff, M., Mishra, H.S., Tyrväinen, L., Haase, D. (2022) *Citizen science methodology* (M3.9). H2020 project CLEARING HOUSE, grant no. 821242.

Trivino, M., Pohjanmies, T., Mazziotta, A., Juutinen, A., Podkopaev, D., Le Tortorec, E., & Monkkonen, M. (2017). Optimizing management to enhance multifunctionality in a boreal forest landscape. *Journal of Applied Ecology*, 54(1), 61–70.

Whittlesey, S., Biaz, L., Schante, j., De Vreese, R. (2021) *Sino-European Co-design Report* (D3.3) H2020 project CLEARING HOUSE, grant no. 821242.

Wolff, M. (2021). Taking one step further–Advancing the measurement of green and blue area accessibility using spatial network analysis. *Ecological indicators*, 126, 107665.

Wolff, M.; Haase, D. (2022). Accessing the functional connectivity of urban tree systems. Report for Stream 4: Geography of UF-NBS / Multifunctionalities, T2.2 Conducting a comparative, in-depth analysis of case study cities, CLEARING HOUSE.

Wolff, M.; Haase, D.; Priess, J.; Hoffmann, T.L. (2023). The Role of Brownfields and Their Revitalisation for the Functional Connectivity of the Urban Tree System in a Regrowing City. *Land* 12, 333.

Yao, N., Konijnendijk van den Bosch, C. C., Yang, J., Devisscher, T., Wirtz, Z., Jia, L., Ma, L. (2019) Beijing's 50 million new urban trees: Strategic governance for large- scale urban afforestation. *Urban Forestry & Urban Greening*, 44, Article 126392.

Zingraff-Hamed, A., Huesker, F., Albert, C., Brillinger, M., Huang, J., Lupp, G., Scheuer, S., Schlatel, M. & Schroter, B. (2020) Governance models for nature-based solutions: seventeen cases from Germany, *Ambio* 50: 1610 – 1627

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APPENDICES

Appendix 1: Justification for the selection of deliverables and milestones used in this report (D2.2)

Reports	Justification - Comparative information
D1.4 Report on governance, institutional and economic frameworks	Describes the planning families and includes some initial Sino-European comparisons of governance, institutional and economic frameworks.
D1.6 Report on the development of an analytical framework for Clearing House	Section 2.4, pp 12 – 13 similarities and differences between continents ; pp 16 – 18. Analysing governance, institutional and economic frameworks for UF-NBS. Analytical framework pp 23 – 25 (see pages 1 – 2 of this document)
M1.6 Final methodology for analysing governance, institutional and economic framework for UF-NBS	Defines governance, institutional and economic frameworks; research questions: 1. Which institutions, actors, resources, 'rules of the game' and discourses are involved in UF-NBS, how are they characterised and how are these institutions inter-related, if at all? 2. What governance arrangements are in place that impact on the potential or actual delivery of UF-NBS at the project level and multi-tiered levels above the project? 3. What positive and negative economic effects do institutions determine as arising from the delivery of UF-NBS? 4. In respect of governance, analysis and economic, what elements of UF-NBS can be considered as novel or innovative?
D2.1 Mapping the potential of UF-NBS (earlier version found in ECCP)	Section 3.3, p 18 case study comparison of forest area provision and forest are share and tree cover density in 2018. pp 19 – 21 Leipzig as an example of data processing.
D2.1 Report on the exploratory analysis of all the case study cities – final version	This includes the five European cities and the four Chinese cities (Beijing, Xiamen, Guangzhou-Shenzen-Hong Kong and Huabei). The report includes general information, geography of UF-NBS, government and governance of UF-NBS and the strategic objectives in relation to UF-NBS. Comparative factsheets are on p10 (Europe) and p 15 (China). The conclusion has more comparison after EU feedback i.e. similarities and differences in Europe and China; barriers and knowledge gaps.
D3.1, D3.2, D3.3 Guidance for local co-design and co-learning; Local co-design workshop synthesis report; Sino-European co-design report	Useful as used the same categories for each city in Europe and China. Conclusion in D3.2 considers the challenges of comparison (Europe case study cities). Gaps in knowledge for each case study city (Europe and China) are noted.
M3.9 Citizen science methodology	.A concept note that outlines a citizen science framework for CLEARING HOUSE. Useful to understand the knowledge base and development of ideas for comparing citizen science.

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Appendix 2: Justification for the selection of publications/reports used in this report (D2.2)

Chapter	Articles	Justification - Comparative information
Chapter 2 GOVERNANCE AND MANAGEMENT	**KEY COMPARATIVE PAPERS:** Zingraff-Hamed, A., Huesker, F., Albert, C., Brillinger, M., Huang, J., Lupp, G., Scheuer, S., Schlatel, M. & Schroter, B. (2020) Governance models for nature-based solutions: seventeen cases from Germany, *Ambio* 50: 1610 – 1627	Paper identifies governance models for NBS based on 17 cases in Germany.
	Roitsch, D., da Schio, N., Krajter Ostoić, S., Zivojinovic, I., Vuletić, D., Armstrong, A., Czaplarska, A., Baró, F., Whitehead, I., Buiis, A. and De Vreese, R. (submitted in August 2023) Co-production of urban forests as nature-based solutions: motivations and lessons-learnt from public officials, Target Journal *Environmental Science and Policy*	Based on 30-40 interviews in case study cities (Europe) both within and outside of CLEARING HOUSE. Focus on co-production
	COMPARATIVE REPORTS Biaz, L. (2022) *Sustainable funding mechanisms for UF-NBS and cost-effectiveness*, Deliverable from Work Package 2, Task 2.2, Workstream 3, LGI Consulting CLEARING HOUSE.	Based on a workshop in April 2022 in Barcelona with representatives Barcelona, Gelsenkirchen, Krakow, Hong Kong (CLEARING HOUSE city cases) and also Milano, Padova and Paris
	Scheuer, S., Wolff, M., Mishra, H.S., Tyrväinen, L., Haase, D., 2022. CLEARING HOUSE citizen science methodology (M3.9). CLEARING HOUSE	Report on citizen science methodology for CLEARING HOUSE case study cities
Chapter 3 THE GEOGRAPHY OF UF-NBS	**KEY COMPARATIVE PAPERS:** Wolff, M.; Haase, D. (2022). Accessing the functional connectivity of urban tree systems. Report for Stream 4: Geography of UF-NBS / Multifunctionalities, T2.2 Conducting a comparative, in-depth analysis of case study cities, CLEARING HOUSE.	The Wolff and Haase report uses the five CLEARING HOUSE European cities and we therefore have comparable material.
	SINGLE CITY PAPER: Wolff, M.; Haase, D.; Priess, J.; Hoffmann, T.L. (2023). The Role of Brownfields and Their Revitalisation for the Functional Connectivity of the Urban Tree System in a Regrowing City. *Land* 12, 333.	A single-city paper focusing on Leipzig.

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	CONCEPTUAL PAPER Wolff, M., Mascarenhas, A., Haase, A., Haase, D., Andersson, E., Borgström, S., Kronenbergt J., Laszkiewicz E. & Biernacka, M. (2022). Conceptualizing multidimensional barriers: a framework for assessing constraints in realizing recreational benefits of urban green spaces. *Ecology and Society*, 27(2).	A conceptual paper with a framework designed to capture the cumulative and interactive effects of barriers to achieving the recreational benefits of urban green space.
	SINGLE CITY PAPER: Wolff, M. (2021). Taking one step further–Advancing the measurement of green and blue area accessibility using spatial network analysis. *Ecological indicators*, 126, 107665.	A single-city paper focusing on Halle
	SINGLE CITY PAPER: Barber, A., Haase, D., & Wolff, M. (2021). Permeability of the city–Physical barriers of and in UGS in the city of Halle, Germany. *Ecological Indicators*, 125, 107555.	Single city paper offering a comparison of physical barriers of and in UGS in Halle.
	SINGLE CITY PAPER: Jin, J., Sheppard, S., Jia, B. and Wang, C. (2021) Planning to practice: impacts of large-scale and rapid afforestation on greenspace patterns in the Beijing Plain Area, *Forests* 12 (3): 316	Single city paper focusing on Beijing, China
Chapter 4 **THE CITY AND TREES**	Andersson, E., Haase, D., Anderson, P., Cortinovis, C., Goodness, J., Kendal, D., Lausch, A., McPhearson T., Sikorska D. & Wellmann, T. (2021). What are the traits of a social-ecological system: Towards a framework in support of urban sustainability. npj *Urban Sustainability*, 1(1), 1-8.	Conceptual paper exploring the potential of a **traits framework** for understanding social-ecological patterns, dynamics, interactions, and tipping points in complex urban systems
	Cortinovis, C., Geneletti, D., & Haase, D. (2022). Higher immigration and lower land take rates are driving a new densification wave in European cities. npj *Urban Sustainability*, 2(1), 1-14.	Comparative paper exploring urban densification and de-densification trends at the European level
	SINGLE CITY PAPER: da Schio N, Pelgrims C., Vandenbroucke L. Cincinnato S. (in press), *Between liveability and accessibility in Brussels'* Bois de la Cambre, Brussels Studies	Two of the single-city articles focussing on Brussels. One, on the setup of Bois de la Cambre for mobility, leisure, and other uses. A prominent issue is whether motorised traffic through the park should be allowed. It describes and analyses the

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	SINGLE CITY PAPER: da Schio N. & De Lestrange R. (under review) *The park street: striking the balance between mobility, biodiversity, and permanence functions of public space* (Brussels, Belgium)	motivations, socio-demographic profiles and practices of citizens who express different preferences for the development of the park. The second, a research-by-design project on the concept of park streets in the municipality of Woluwe Saint Pierre (WSP) which is on the fringes of the Sonian Forest.

Appendix 3: Full versions of the articles (in chapter/section order)

Chapter 2: Governance and management of UF-NBS

1. **Section 2.1:** Zingraff-Hamed, A., Huesker, F., Albert, C., Brillinger, M., Huang, J., Lupp, G., Scheuer, S., Schlatel, M. & Schroter, B. (2020) Governance models for nature-based solutions: seventeen cases from Germany, *Ambio* 50: 1610 – 1627

2. **Section 2.2:** Roitsch, D., da Schio, N., Krajter Ostoić, S., Zivojinovic, I., Vuletić, D., Armstrong, A., Czaplarska, A., Baró, F., Whitehead, I., Buiis, A. and De Vreese, R. (submitted in August 2023) Co-production of urban forests as nature-based solutions: motivations and lessons-learnt from public officials, *Environmental Science and Policy*

3. **Section 2.3:** Biaz, L., *(2022) Sustainable funding mechanisms for UF-NBS and cost-effectiveness*, Deliverable from Work Package 2, Task 2.2. LGI Consulting, CLEARING HOUSE .

4. **Section 2.4:** Scheuer, S., Wolff, M., Mishra, H.S., Tyrväinen, L., Haase, D. (2022) *Citizen science methodology* (M3.9). CLEARING HOUSE.

Chapter 3: The geography of UF-NBS: exploring questions of connectivity and accessibility

1. **Section 3.1**: Wolff, M.; Haase, D. (2022). *Accessing the functional connectivity of urban tree systems.* Report for Stream 4: Geography of UF-NBS / Multifunctionalities, T2.2 Conducting a comparative, in-depth analysis of case study cities, CLEARING HOUSE.

2. **Section 3.2:** Wolff, M.; Haase, D.; Priess, J.; Hoffmann, T.L. (2023). The Role of Brownfields and Their Revitalisation for the Functional Connectivity of the Urban Tree System in a Regrowing City. *Land* 12, 333.

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3. **Section 3.3:** Wolff, M., Mascarenhas, A., Haase, A., Haase, D., Andersson, E., Borgström, S., Kronenbergt J., Laszkiewicz E. & Biernacka, M. (2022). Conceptualizing multidimensional barriers: a framework for assessing constraints in realizing recreational benefits of urban green spaces. *Ecology and Society*, 27(2).

4. **Section 3.4:** Wolff, M. (2021). Taking one step further – Advancing the measurement of green and blue area accessibility using spatial network analysis. *Ecological indicators*, 126, 107665.

5. **Section 3.5:** Barber, A., Haase, D., & Wolff, M. (2021). Permeability of the city–Physical barriers of and in urban green spaces in the city of Halle, Germany. *Ecological Indicators*, 125, 107555.

6. **Section 3.6:** Jin, J., Sheppard, S., Jia, B. and Wang, C. (2021) Planning to practice: impacts of large-scale and rapid afforestation on greenspace patterns in the Beijing Plain Area, *Forests* 12 (3): 316

Chapter 4: The city and the trees: how social and ecological dynamics mirror each other in the urban space.

1. **Section 4.1:** Andersson, E., Haase, D., Anderson, P., Cortinovis, C., Goodness, J., Kendal, D., Lausch, A., McPhearson T., Sikorska D. & Wellmann, T. (2021). What are the traits of a social-ecological system: Towards a framework in support of urban sustainability. npj *Urban Sustainability*, 1(1), 1-8.

2. **Section 4.2:** Cortinovis, C., Geneletti, D., & Haase, D. (2022). Higher immigration and lower land take rates are driving a new densification wave in European cities. npj *Urban Sustainability*, 2(1), 1-14.

3. **Section 4.3:** da Schio N, Pelgrims C., Vandenbroucke L. Cincinnato S. (in press), *Between liveability and accessibility in Brussels'* Bois de la Cambre, Brussels Studies

4. **Section 4.4:** da Schio N. & De Lestrange R. (under review) *The park street: striking the balance between mobility, biodiversity, and permanence functions of public space* (Brussels, Belgium)

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