Can nature-based solutions improve quality of life?

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Abstract

In the wake of the global climate, biodiversity and health crisis, cities are increasingly looking for solutions to help them 'build back better' to create a more sustainable and resilient future that improves the quality of life of urban inhabitants. Against this backdrop, Nature-based solutions have emerged, promising to tackle a multitude of different societal challenges by using urban nature to create, manage and restore ecosystems to provide quality of life. This thesis asks does the concept of Nature-based Solutions (NBS) relate to concepts that underpin the quality of life by unpacking the interconnected and dynamic relationship between the management and governance of NBS, socio-economic and socio-political factors at a macro and mesoscale. To achieve this aim, this thesis presents a novel mixed-method approach that integrates exploratory data analysis, geometric data analysis, thematic mapping, and quantitative text analysis to untangle these complex phenomena.

The thesis presents three empirical chapters: the first examines how the distribution of the characteristics of NBS relates to different socio-economic conditions across European Regions, and the second examines how changes to nature conservation paradigms that underpin NBS have influenced the interaction between governance, participation, citizen involvement, and in turn quality of life. Finally, the last empirical chapter examines how different types of green and blue space and ecosystem services influence adverse health outcomes at a population level.

By examining the interactions between different characteristics that influence the practice and implementation of NBS with different social and economic determinants of ill-health, this

thesis highlights the lack of consideration of entrenched, social, and economic conditions that adversely affect urban QoL in the design, planning, implementation, and monitoring of NBS despite the repeated reference to the importance of NBS for good QoL in the scientific literature. The design, planning and implementation of NBS are rarely influenced by factors such as the ageing structure of the population, lack of good quality housing with access to salutogenic or the loss of urban biodiversity, or the interactions between these phenomena and their impact on QoL despite the urgency of the climate challenge and the imperative for cities to transition to sustainability. Furthermore, this thesis finds that while pathways influence the implementation of NBS at different scales, they are deeply entwined and contested, often hindering the potential of NBS to positively influence the upstream social and economic determinants of ill health and unjustly distribute their benefits.

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List of Abbreviations

BMI	Body Mass Index
CDV	Cardiovascular Disease
CSDH	Commission on the Social Determinants of ill Health
EDA	Exploratory Data Analysis
EU	European Union
EC	European Commission
GDA	Geometric Data Analysis
IUCN	International Union for Nature Conservation
MFA	Multiple Factor Analysis
MCA	Multiple Correspondence Analysis
NBS	Nature-based Solutions
NCDs	Non-communicable diseases
PCA	Principal Component Analysis
PM	Particulate Matter
QoL	Quality of Life
SEP	Socio-economic position
SDOH	Social Determinants of Health

EU-SILC	European Union Social Indicators of Living Conditions
UNA	Urban Nature Atlas
UA	Urban Audit
WWF	World Wildlife Fund
WHO	World Health Organisation

Acknowledgements

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1 Introduction

1.1 Background and Context

Cities are complex adaptive systems that provide hubs for people, infrastructure and commerce situated within complex ecosystems that face immense challenges, including climate change, overexploitation of natural resources and demographic ageing (Burkhard et al., 2010; Hasse et al., 2014). In a recent editorial, the International Union for Nature Conservation (IUCN) and Geneva Environment Network (2021) commented that we are witnessing a triple planetary crisis in which three historical trajectories have converged: rise in global temperatures due to changing climate, reproduction and widening of social and economic inequalities and acceleration of the biodiversity loss, all of which more recently have collided with the Covid-19 pandemic. Even before the Covid-19 pandemic (and the implementation of isolation and social distancing measures) began, the complex interrelationships between urbanisation processes, densification of built-up areas, climate change, a reduction in the quality and quantity of green space pose a significant threat to the urban health of people in cities (Kabisch & van de Bosch, 2017).

Academics, practitioners, policy and decision-makers alike agree that now more than ever, both developed and developing cities must look for solutions that can help them build back better to create a more sustainable and resilient future that improves the quality of life (QoL) of urban inhabitants. Against this backdrop, Nature-based solutions (NBS) emerged in the early 2000s as cities looked for solutions that would help them progress sustainable development goals and transition to sustainability (Franzteskaki 2019; Raymond et al., 2018; Almassy et al., 2017). The IUCN and European Commission (EC) argue that NBS are a key instrument for climate adaptation and mitigation and greening cities (McKenna and Davis, 2020). To galvanise support the EC published 'Nature-based solutions to address societal challenges' (Cohen-Shacham et al., 2016) and 'Towards an EU Research and Innovation policy agenda for Nature-Based Solutions & Re-Naturing Cities' (European commission, 2015). More recently, transnational actors have also advocated that NBS are an essential tool for catalysing action biodiversity through the Post-2020 Global Biodiversity Framework and Convention on

Biodiversity 2050 Vision of 'Living in harmony with nature' (United Nations, 2021). These actors also suggest that NBS may aid post-Covid-19 recovery by helping to tackle the rise in unemployment, inequality and environmental degradation (WWF, 2020, 2021) by providing an array of ecosystem services that could help re-integrate nature and natural processes into cities, but also mitigate against climate change and improve quality of life (QoL) (Kabisch and van de Bosch, 2017; Balian et al., 2016, Cohen-Shacham et al., 2016; EC, 2015; Potschin et al., 2014). However, both policy documents and academic literature often adopt normative assumptions about the potential of NBS to address multiple societal challenges and lack clarity on how the principals that underpin the framework relate to interrelated concepts such as QoL. Similarly, scholars (e.g. Mace, 2014; Cohen-Shacham et al., 2019) claim that nature conservation paradigms have evolved from those that externalise nature to one that promotes the benefits of NBS equally among people and nature. However, it is not clear how these changes have influenced the implementation of NBS by practitioners and in turn, their influence on the QoL of urban inhabitants.

1.2 Research Questions

The research presented in this thesis is focused on the following research questions:

- How do the different characteristics (such as different types of ecological domains, ecosystems services and governance) that influence the implementation of NBS relate to key concepts that underpin QoL?
- Given the lack of evidence of the impact of NBS across different scales, how can different forms of knowledge and methodological approaches be integrated to unpack the complex interconnections between NSB and QoL?
- How does the distribution of different attributes of NBS relate to the distribution of divergent social and economic trends that influence QoL to vary across urban Europe?
- How have changes to nature conservation paradigms that underpin NBS influenced the interaction between governance, participation, citizen involvement, and QoL?

- How do different types of green and blue space and ecosystem services influence adverse health outcomes at a population level, and is there any variation in the effect size across different types of NBS?
- How does the temporal pattern of distribution of the characteristics of NBS relate to different socio-economic conditions that influence QoL, and is there any evidence of patterns of clustering based on the distribution of social and health inequalities?

1.3 Theoretical Framework, objectives and Empirical Contribution of the Thesis

This thesis adopts the meaning of NBS developed by the IUCN that defines NBS as: "actions to protect, sustainably manage and restore natural or modified ecosystems, which address societal challenges (e.g. climate change, food and water security or natural disasters) effectively and adaptively, while simultaneously providing human well-being and biodiversity benefits" (Cohen-Shacham et al., 2016, p2). This conceptualisation was further developed by the European Commission which aimed to centre the benefits of NBS on social and economic goals. In this way the definition evolved to: "actions which are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes, and seascapes, through locally adapted, resource-efficient and systemic interventions" (Wild et al., 2020, pp. 3). Both of these definitions are used widely used across academic, policy and decision-making circles, but differ slightly leading to criticism due to their pluralist framing and simplicity (or vagueness). Chapter 2 discusses these issues debates and other broader debates surrounding the framing of NBS.

Drawing on the conceptual framework for NBS developed by the IUCN and European Commission, this thesis aims to explore how the concept of Nature-based Solutions (NBS) relates to concepts that underpin the quality of life by unpacking the interconnected and dynamic relationship between the management and governance of NBS, socio-economic and socio-political factors at a macro and mesoscale. Scholars posit that QoL is a multifaceted

concept that is difficult to define (Murgas, 2018; Pacione, 2003), but it is commonly embedded within frameworks that aim to advance climate change and urban development agendas. To define QoL, this thesis draws on Pacione's (2003), Shafer's (2000), and El Din et al., (2013) conceptualisation of QoL and, in doing so, defines QoL as a network of relationships between the natural environment, urban fabric and infrastructure, different structural and institutional conditions that influence life quality. The conceptual framework for this definition is discussed in Chapter 2.

Fudge et al., (2020), Grant et al., (2017) and Whitmee et al., (2015) suggest that complex flows and networks of relations embody and mediate socio-ecological and socio-technical processes, and the structural and functional characteristics of cities directly or indirectly influence the urban health affecting QoL. This claim is supported by evidence published by the World Health Organisation (WHO) (2016) who suggest that the synergist effects of these processes are responsible for over 70% of deaths caused by non-communicable diseases (NCDs) (including obesity and cardiovascular disease) globally each year. Furthermore, recent research by Anenberg et al., (2020) and Prüss-Ustün et al., (2019) also suggests that the adverse effects of climate change have increased mortality rates in cities with a low to medium socio-economic index (Murray et al., 2020). Given the rhetoric around NBS, this thesis aims to advance understanding of the impact NBS have on QoL and determine if these solutions deliver the benefits to urban health advocated by the framework or do they reproduce existing inequalities and create problems of environmental justice (see Cousins, 2020; Kotsila et al., 2021).

To address the gaps outlined above, this thesis aims to advance understanding of the conceptual relationship between NBS and QoL through four objectives:

- To further develop conceptual understandings of the relationship between NBS and QoL by adopting an innovative methodology that draws on different sources of knowledge and methods of analysis to allow the pathways that influence interaction between these complex phenomena to emerge.

- To explore how the distribution pattern of NBS relates to the pattern of uneven development in different regions and cities of urban Europe and the influence on QoL.

- To advance understanding of how the relationship between nature conservation paradigms that underpin NBS and different modes of governance, participation and citizen involvement has evolved and how the patterns that emerge relate to QoL and environmental injustice.

- To explore how the impact that different types of ecological domains and ecosystems services provided by NBS relate to population health, focusing on mortality related to respiratory and heart disease and all-cause mortality, including the relationship with gender.

For the analysis the region is used as an analytical unit (Paasi, 2020; Riding, 2018) to unpack the distribution of the uneven geographies of NBS related to complex interrelationships between different demographic trends, social and socio-economic conditions that influence QoL within and across different scales. In doing so, the definition of a region adopted in draws on Jones (2017) and Jones and Macleod (2004). They argue that a region is multiple entity, a territorial or symbolic shape created by drawing political entity entities economic exchange, places of cultural capital, and belonging. In the second and third empirical chapters, the thesis transitions from macro to a mesoscale of analysis using the city as the unit of analysis. In doing so, the thesis conceptualises the city as a complex hybrid system. Bettencourt (2015) and Swyngedouw (1996) portray cities as complex systems that consist of technological systems and built urban infrastructure intertwined with ecological systems to create hybrid ecosystems (Grimm et al., 2016).

Using the city as an analytic unit advances our understanding of how NBS can disrupt the complex interrelationship between urban diversity, the built environment, income inequality and poor urban health at a population level. Despite growing evidence that the relationship between urban health and NBS could mediate social inequalities that lead to poor health (see Mitchell and Popham (2008), Mitchell et al., (2015), Wolch et al., (2014)), there is a lack of evidence of the impact of different types of NBS have on urban health. This thesis defines

urban health as "the health of people living in cities and the healthy functioning of cities" (Gatzweiler et al., 2020, pp.2). Key conceptual debates surrounding health in cities and the relationship between blue and green space types and their ecosystem services are discussed throughout the thesis. The research explores recent debates articulated by Van de Berg et al., (2015) and Van den Bosch (2017), who argue the nexus between NBS, social and economic inequality and health is not central to its conceptual framing of NBS and consequently, there are uncertainties about claims made about the impact of NBS on social inequality (Jennings et al., 2016: Michell et al., 2015) or urban health (Dumitru et al., 2020; Van de Berg et al., 2015).

Other scholars argue lack of evidence of the impact of NBS on complex interactions between health and social inequality could lead to the maldistribution of distribution of the benefits of NBS and exclusion of vulnerable groups from processes that encourage agency with infrastructure creating issues of environmental justice. The key conceptual debates related to environmental justice are revisited but the research adopts the definition developed by Hollifield et al., (2017) to examine how the distribution of NBS relates to environmental justice focusing on distributive, recognition, procedural injustice, and justice as capability.

1.4 Relationship to the EC Horizon 2020 NATURVATION programme

This thesis is a deliverable of the EC Horizon 2020 NATURVATION programme. The programme aimed to evaluate the performance of NBS in cities and how they foster innovation through cross-collaboration between different municipal actors and society (Bulkeley 2016; Naturvation, 2017). Led by Prof. Harriet Bulkeley at Durham University, the programme involved 14 institutions from diverse disciplines and six Urban Regional Innovation Partnerships or URIPs that provide on-the-ground innovation hubs to help understand the potential of NBS.

This thesis forms part of Work Package 2, which developed a database of NBS with 1000 examples of NBS to understand the distribution pattern within and across cities, and the relationship with key variables that influence QoL (Almassy et al., 2017). The research presented in this thesis contributes to these aims by assessing the urban distribution of NBS

and how this relates to social, economic and health factors that influence QoL. Findings from this thesis were published in "Deliverable 2.4 A study of the relationship between NBS, socio-economic conditions and health outcomes" in 2021. This report investigated how the distribution of NBS relate to structural conditions prevalent across urban Europe. It provided the first review of the relationship between NBS and health, focusing on mortality (all-cause, all-cause mortality related to biological sex, infant mortality, and mortality due to respiratory and heart disease) across European cities.

1.5 Research Methods

Methodologically, the thesis begins grounded in post-positive ontology utilising exploratory data analysis and thematic mapping in ArcGIS at a macro scale influenced by New Regional Geographies (Riding, 2018; Paasi, 2020) and Visualisation Cartography (MacEachren, 1995; MacEachren and Canter, 1990) to unpack the relationship between divergency social and economic conditions that influence QoL across urban Europe (Chapter 4). In the second and third empirical chapter of the thesis, ontologically, the thesis evolved influenced by self-reflection and lessons learnt because of working with secondary data (Chapter 3). Chapter 5 responds to positive critiques of representation by drawing on quantitative relational methods such as Geometric Data Analysis to analyse the meso-level interactions between different modes of governance, participation, and citizen involvement and how these interactions have been influenced by changing paradigms that underpin the NBS concept and in turn, how these relationships influence QoL in cities. The final empirical chapter, Chapter 6, examines the relationship between different characteristics of NBS and health outcomes using inferential statistics and analysis of the size effect of the relationship. Given the risk of ecological fallacy in the data, these results are triangulated with quantitative text analysis of qualitative commentaries published in the Urban Nature Atlas (UNA). Thus, it is argued that this thesis offers an innovative methodological approach that aims to 'follow the data' by integrating different methodologies adopted in cartography (MacEachren, 1995; MacEachren and Canter, 1990), geometric data analysis applied in economic geography (Yueng, 2002) and sociology (Cunningham, 2020), and relational statistical methods to unpack how the different attributes of NBS (such as how they are governed and engage with society) interact with complex systems

to influence population health in cities. The rationale for this approach is explained in the methods chapter (Chapter 3), but centres my approach on Boggs and Rantisi (2003), who argue "empirical reality is too complex to be compartmentalised; it defies single paradigms" (pp.111). Faulconbridge (2017) and Boggs and Rantisi (2003) argue inter-relations between different attributes are shaped by the contexts in which they are produced and subject to random disturbances.

Like Ricker (2018) and Dalton and Thatcher (2018), my positionality takes a reflective stance to respond to the challenges and disturbances encountered due to utilising both primary data collected by master's students working for Naturvation and open-source secondary data. Ricker argues that patterns in big data are influenced by epistemologies of individual researchers, computer scientists, and database administrators who created and maintained the data used in this study. Hence, it is essential to pay attention to the underlying epistemological effects of the creation of big data and consider what has been opened and closed off during primary data collection, creating design the UNA.

1.6 Thesis Outline

This chapter, which sets out the general aims, objectives and research questions for the research, is followed by Chapter 2, which presents a review of relevant literature that are drawn upon in the analysis and discussion of the three empirical papers that form Chapters 4, 5 and 6 of the thesis. It is helpful to begin with, a critique of the definition and conceptualisation of NBS and how these relate to similar concepts such as Ecosystems Services and Greenspace, but also how normative and hegemonic narratives have influenced the enactment and framing of NBS. Chapter 2 also defines QoL and presents a review of the existing evidence of the relationship between socio-economic position and health, particularly the relationship between key health characteristics such as different types of ecological domain, ecosystems services and health.

Scholars (Cohen-Shacham et al., 2016; Frantzeskaki, 2019; Raymond et al., 2017; Nesshover et al., 2017) posit that NBS can utilise the power of urban nature to create, protect or restore

ecosystems by creating bundles ecosystems services to tackle interrelated societal challenges and improve QoL. This assumes that socio-ecological systems are compatible (Tzoulos et al., 2021) despite the lack of studies that unpack how complex concepts such as social and health inequality (Dumitru et al., 2020; Van de Berg et al., 2015) relate to NBS, leading to what Aygeman (2005) describes as an 'equity deficit' in conceptualisation. Hence, Chapter 2 provides a review of current academic thinking on how the conceptual framework for NBS relates to environment justice literature and how this is applied in the thesis.

The literature review is followed by a reflection on the methodology (Chapter 3) used for analysing data collected by the NATURVATION project and secondary, open data published by the Urban Audit. This takes the form of a discussion of thematic mapping, geometric data analysis, inferential statistical analysis, and relational statistical methods such as co-occurrence network analysis. This chapter takes the form of a discussion of the theoretical rationale for using each method, drawing on postpositive, new region geography and relation literature. Ethical considerations of the research are also discussed.

Chapter 4, 5 and 6 of the thesis have each been submitted to a journal and are under review. These chapters contain the specific literature and methods for each chapter in the format of an article and the subsequent results, analysis and discussion. The papers submitted are as follows:

- Chapter 4, entitled "Distribution of NBS across Europe", has been submitted to the Journal of Land Use Policy.

- Chapter 5, entitled "Temporal distribution of Nature-based Solutions, social and health inequalities in European cities Temporal distribution of Nature-based Solutions and Quality of Life in European", has been submitted as a journal article in the Special Issue: Just Cities Special Issue Symposia and in the Journal of Environmental Planning and Policy, World Climate Justice Conference and Society and Nature Conference.

Chapter 6, entitled “6 A novel approach to quantitative analysis of the relationship between Nature-based Solutions and Health at the City-Scale” was the subject of a webinar with ActNBS in December 2020 and an editorial with Network Nature in spring 2021.

Chapters 4 and 5 were written collaboratively with Dr Niall Cunningham and Prof. Louise Bracken. Dr Cunningham and Prof. Bracken played a vital role in reviewing and editing draft manuscripts. The conceptualisation, methodology, data analysis and visualisation and preparation of the original draft, edited versions and writing of complete drafts were done by Clair Cooper.

Chapter 4 explores the relationship between the geographies of NBS and the underlying social and economic factors that influence QoL across Europe and Chapter 5 uniquely considers how NBS, health inequality and urban deprivation are related using Multiple Factor Analysis. The final empirical chapter (Chapter 6) the thesis takes a novel approach that combines Pearson's Chi-Squared, Cramer's V size effect analysis with quantitative text mining approaches such as co-occurrence network analysis and multidimensional scaling to examine how some of the key attributes of NBS such as their ecological domains, ecosystems services and mode of governance impact on health outcomes in cities. Finally, Chapter 7 the conclusions and recommendations for further research are presented to answer the research questions set out in section 1.2.

The next Chapter of the thesis reviews the key definitions of NBS and discusses the ongoing conceptual debates that have co-evolved through practice and research. Then, critical theoretical debates in quality of life discourse are explored including how the concept is defined and relates to interrelated concepts such as socio-economic position and health. Finally, key theoretical debates of environmental justice and how these are used in the thesis are discussed.

2 Literature Review

Nature-based solutions (referred to as NBS hereafter) is often referred to as a ‘flagship’ term (Kabisch et al., 2016); umbrella concept or framework that uses or manages nature to address intertwined impacts of climate change and urbanisation by reconfiguring the relationship between people, urban biodiversity and the sustainable use, management, or restoration of ecosystems (Balian et al., 2016; Raymond et al., 2017; Frantzeskaki 2019). This chapter sets the scene for the three empirical chapters that follow by reviewing the key conceptual debates that underpin NBS and concepts that underpin the different societal challenges claimed to be addressed by NBS. The latter focus on the quality of life, its interrelationship with socio-economic position, health inequality and environmental justice. To begin this journey, section 2.1. reviews the key definitions of NBS and elaborates on ongoing conceptual debates that have co-evolved through practice and research. Section 2.2 to 2.5 discuss critical theoretical debates in quality of life research and elaborates on how it is defined and used in the thesis with reference to socio-economic position and health. Finally, Section 2.6 examines key theoretical debates of environmental justice and how these are used in the thesis.

2.1 Introducing Nature-Based Solutions

Action on what researchers, policymakers and practitioners refer to as NBS has slowly evolved over time and appears under many guises (such as natural solutions, green infrastructure, ecosystem adaptation) (see reviews by Nesshover et al., (2017) and Seddon et al., (2020)). However, these solution-orientated actions were not given a formal name in scientific or grey literature until the World Bank report published the impact of the actors' climate change mitigation and adaption investments in the late 2000’s (Mittermeier et al., 2008). Around this time, important paradigm shifts were also occurring in nature conservation; people were not just passive beneficiaries of efforts to externalise nature’s benefits (Mace, 2014). The 'notion of nature' could be harnessed as a solution to address different societal problems for the equal benefit of both people and urban biodiversity (Nesshover et al., 2017; Cohen-Shacham et al., 2016). Transnational actors such as the International Union for the Conservation of Nature (IUCN) and the European Commission subsequently adopted and promoted NBS as a means

to mitigate and adapt to climate change, address interrelated problems such wate insecurity, alleviate flood risk and tackle poverty by stimulating economic growth (Nesshover et al., 2017; Cohen-Shacham et al., 2016; Seddon et al., 2020).

2.2 Definitions of NBS

The most frequently adopted definition of NBS in the literature is the definition developed by the IUCN, which suggests NBS are: *"actions to protect, sustainably manage and restore natural or modified ecosystems, which address societal challenges (e.g. climate change, food and water security or natural disasters) effectively and adaptively, while simultaneously providing human well-being and biodiversity benefits"* (Cohen-Shacham et al., 2016, p2). Later, the European Commission refocused the definition of NBS to centre it on the achievement of social and economic goals through the deployment of blue-green infrastructure projects (Wild et al., 2020; Seddon et al., 2020). Consequently, the conceptualisation of NBS evolved to include idealisations of nature that could undermine urban biodiversity goals such as biomimicry (Balian et al., 2016):

"*actions which are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions"* (Wild et al., 2020, pp. 3).

The ICUN definition supports hybrid thinking by recognising the complex and dynamic intertwined relationship between people and urban biodiversity within socio-ecological systems (Eggermont et al., 2015; Folke et al., 2021; Welden et al., 2020; Whatmore, 2002) while the European Commission's approach is focused on innovation and socio-economic gains (European Commission, 2015; Eggermont et al., 2015; Seddon et al., 2020). Taken together, both definitions overlap, advocating the use of natural and self-sustaining processes to help society transition to sustainability, but a review of the evidence suggests fundamental conceptual differences. Given this evidence, it could be argued that widescale adoption of the

European Commission definition could misuse municipal actors and stakeholders (Albert et al., 2017; Nesshover et al., 2017) if narratives externalise nature are left unchecked.

In light of these differences, some scholars have attempted to clarify the definition by changing the language used to frame the concept. A study by Dorst et al., (2019) refers to NBS as “interventions based on nature that are envisaged to address sustainability challenge” (p1) while Frantzeskaki et al., (2019, 2017) explain that NBS may be 'stand-alone solutions or hybrid approaches' that may incorporate technology or engineered features. Similarly, the Naturvation project defined NBS as deliberate, physical or discursive interventions inspired by or supporting nature that seeks to change or enhance the function of an area or structure to address societal challenges (Bulkeley, 2016).

With the exception of the definition developed by Dorst et al., (2019), this thesis agrees with arguments made by Kosila et al., (2020) and Tzoulos et al., (2021) that many of these definitions apply normative statements that assume action by cities will result in different societal problems being tackled 'simultaneously’ and that they will in turn deliver benefits for human well-being without considering the state or capacity of ecosystems to achieve these goals (Plumpre, 2020). Similarly, Welden et al., (2020, 2021) and Woroniecki et al., (2020) argue that both normative assumptions and hegemonic narratives that neoliberalise nature (Albert et al., 2019; Balian et al., 2014; Bakker, 2010; Castree, 2008a, 2008b) persist across research, policy and practice despite claims made that the IUCN definition of NBS is the more widely accepted. However, these papers are based on a limited number of qualitative studies with comprehensive, quantitative studies that trace the influence of ‘human-nature dichotomy’ or ‘NBS for people and nature’ framings on different types of NBS and how these evolve are over time are lacking. Thus, this thesis will ask: is the transition from the externalisation of nature paradigm (prevalent from 1990 to the late 2000s) to that which focuses on 'equal benefits for society and nature (2010 onwards) evident across the cases of NBS included in the Urban Nature Atlas?

2.2.1 What are NBS?

While critiques by Welden et al., (2020, 2021) and Woroniecki et al., (2020) are concerned with dichotomous framings of NBS, it is also helpful to engage with literature that asks, 'what is an NBS?' To date, the literature has largely focused on how the concept relates to other similar concepts, including, but not limited to, Nature-based Strategies (Hobbie and Grimm, 2020; Kondo et al., 2015), Nature-based Infrastructure (Sutton-Grier et al., 2018), Nature-based Approaches (Gulsrud et al., 2018), and Natural Climate Solutions (Seddon et al., 2019: Grimscom et al., 2017) (see Seddon et al., (2020) or Nesshover et al., (2017) for a more comprehensive list). It is not the scope of the thesis to examine these concepts in detail, but Nesshover et al., (2017) and Pauliet et al., (2017) argue that NBS aims to bring these, and other similar concepts (such as Green Infrastructure and Ecosystem-based Adaptation), into one overarching framework despite their varying focus and differences in framing that vary from reductionist to holistic. Given the breadth of concepts considered NBS, some scholars have criticised its vagueness, arguing that it is just another poorly defined 'buzzword' with 'lofty potential' (Albert et al., 2017; Maes and Jacobs, 2017; Folke et al., 2021). It is not surprising that scholars are critical of the concept given the extent of its framing and lack of consideration of the interconnectivity and interconnections between them. Furthermore, none of these studies consider how the definition of NBS relates to definitions of blue or green space and how these relate to different definitions of nature.

2.2.2 Relationship between NBS, definitions of urban greenspace and the notion of nature

Only Almassy et al., (2017), clarify how NBS (and other overlapping concepts) relate to different conceptualisations of blue or green space, referred to by Naturvation (and hereafter as ecological domains). Almassy et al., argue existing greenspaces or structures can only be considered as an NBS if its functioning or structure has been transformed to create multiple features that help address different societal challenges solutions. However, these can include urban parks and forests, community gardens and allotments, derelict spaces with rewilded areas, greenspace connected to grey infrastructure, blue spaces (such as wetlands or lakes), greenspace that is indoor or connected to the external fabric of buildings (such as green roofs or walls) and green areas for water management. Hence, it could be argued that NBS is, in

effect, a 'collective' concept given the breadth of its framing, overlap between concepts and the range of different types of greenspaces that it encompasses. Hence, it is helpful to examine how the literature on what constitutes an NBS relates to the literature that defines greenspace.

Like NBS, Taylor and Hochuli (2017) argue greenspace is also a contested concept with different terminology that is used across disciplines due to uncertainty about how to describe its constitute flora and fauna in terms of its degree of 'naturalness' or pristine nature (Box and Harrison, 1993). This is also evident in the writing of World Health Organisation (WHO) and English Nature; WHO define urban greenspace as *"urban space covered by vegetation of any kind"* (WHO, 2016, pp.7) and classifying it into three categories: smaller green spaces (such as street trees), greenspaces not available for public access or recreation (such as green roofs), and larger green spaces that provide social and recreation functions such as parks or playgrounds) (WHO, 2016). In contrast, Harrison (1996) define natural greenspace as '*land, water and geological features which have been naturally colonised by plants and animals and which are accessible on foot to large numbers of residents'* (Harrison, 1996, pp.1) with four main types of green space in urban areas: remnants of natural systems, agricultural land, private gardens and public parks, habitats which develop on disused urban and industrial sites awaiting development (Harrison, 1996). Similarly to conceptualisations of NBS, these definitions comprise a broad range of different rural and urban spaces with flora and fauna. However, like NBS, they lack any consideration of what constitutes urban nature.

Studies by Castree (2011) and While et al., (2004) highlight that green corridors and urban parks have a long history of being used as mediator or an ecological barrier to address problems caused by rapid urbanisation since the early nineteenth century. Hence, it is useful to consider the writing of Smith (2008), Castree (2011) and Whitehead (2003), who argue that much of the material landscape of greenery that exists in cities today is the product of socio-cultural production. Smith (2008) also argues that most of the today's nature is anthropogenic 'second nature' commodified through urbanisation and neoliberisation. Parallels between these socio-cultural natures and NBS are evident in the literature leading Schaubroeck (2017) to challenge the notion that NBS are natural or nature-based solutions. The author argues that irrespective of the degree of 'naturalness', NBS should add value by co-existing, complementing or

providing alternative options to human or industrial solutions. However, it could be argued that Schaubroek appears to privilege the externalisation of nature over the notion of equal benefits for nature and society. Thus, considering this evidence, this thesis considers NBS to be actions that improve the biodiversity and reconnect people with nature through the use or management of ecosystems (natural, man-made or modified) are envisaged to tackle interrelated societal problems. The NBS may be constituted as different forms of socio-cultural natures or different types of blue or green space as defined by Taylor and Hochuli (2017) and Harrison (1996) and Almassy et al., (2017).

2.2.3 Umbrella Concept or Concept of Frames?

Lack of clarity of definition and the breadth of the framing also led to criticism that NBS is a 'concept of frames' of nature that fails in its attempt to connect a host of interrelated concepts without substantial research into their interrelationships and interconnections (Woroniecki et al., 2020) leading to conceptual diversification (Dimutri and Wend, 2021). However, Welden et al., (2021) argue that NBS can only support social change if the concept is reframed away from the human-nature dichotomy to focus on more inclusive, collaborative, and interconnected framing. Whilst paying attention to these critiques, this thesis draws on the most used conceptual frameworks of NBS in policy and practice to aid our understanding of how these conceptual frames may evolve to deliver the solutions that society urgently needs to adapt and mitigate against climate change. Some scholars have attempted to improve the conceptualisation of NBS by making peripheral changes that simply refocus the framework on challenge-orientated blue-green infrastructure projects (Albert et al., 2019) or argue that biodiversity goals should go beyond traditional conservation principles to alleviate poverty by encouraging economic development and efficient governance. A study by Eggermont et al., (2017) attempts to clarify linkages between NBS and other similar concepts by proposing a typology of NBS defined by the level of engineering or management applied to ecosystems and the degree of stakeholder involvement. However, while these studies aim to strengthen conceptual linkages between similar concepts or refocus the framing of NBS on action on societal challenges or prioritising urban biodiversity improvements, none of these studies elaborate on conceptual linkages and interrelationships with key theoretical debates that

underpin different societal challenges (Cousins, 2021; Calderon et al., 2021; Pineda-Pinto et al., 2021; Woroniecki et al., 2020). Nor do they explore how they fit together to ensure an integrated approach when operationalised (Maes and Jacobs, 2017). Scholars (Nesshover et al., 2017; Pauliet et al., 2017; Woroniecki et al., 2020) argue that exclusion of specific knowledge during the development of the concept, lack of clarity and plurality of framing could lead to unintentional inequitable distribution of NBS benefits or 'nature' being used as a sustainability or cultural fix (While et al., 2004; Long and Rice, 2019; Loughran 2020) to tackle social crises through a process of entrepreneurialism and marketisation (Madanipour et al., 2014).

2.3 NBS and Quality of Life

2.3.1 Definition of Quality of Life

Nature plays a pivotal role in the quality of life (QoL) recognised in the Global Standard for NBS (ICUN, 2020), describing our relationship with nature as fundamental to human existence and essential for 'good life quality'. Conceptual guidance and literature (for example, Cohen-Shacham et al., 2016, European Commission 2015, Kabisch et al., 2016, Raymond et al., 2017) also refer to the relationship between NBS and QoL. However, they do not explain how they define the concept or how it is related to the concept. Hence, it is helpful to consider key theoretical debates that underpin the concept and explore how these conceptually link to NBS.

QoL is a contested, multifaceted construct and interdisciplinary field of study with no agreed definition that is more akin to a conceptual framework than a theory (Murgas, 2018; Pacione, 2003). QoL commonly describes the nature and conditions of life experienced by an individual or a community that encompasses the physical, psychological, social, spiritual, and economic aspects of life (Yamaguchi, 2015; Land and Sirgy, 2012; Das, 2008) and the degree of congruence or dissonance with the natural environment (Lopes and Camanho, 2013). In contrast, public health defines QoL as a *"state of complete physical, mental and social well-being, and not merely the absence of disease and infirmity"* (World Health Organisation (WHO), 1947, pp.13). WHO later broadened the scope of the concept to acknowledge the dynamic interrelationship between subjective and objective dimensions, adding "…. *and individuals perception of their life position in the context of culture and value systems in which*

they live and in relation to their goals, expectations, standards and concerns" (WHO, 1998, pp.551). Hence, like NBS, QoL is an umbrella concept that has a broad framing with different interpretations and many similar overlapping concepts that include but is not limited to: well-being (Atkinson, 2013; Schwanen and Atkinson, 2015), life satisfaction (Sirgy, 2012), geographies of happiness (Smith and Reid, 2018; Ballas and Dorling, 2013), life quality (Pacione, 1986; Marons and Simpson, 2011), urban QoL (Shafer et al., 2000, Serageldin et al., 2016). It is not the role of the thesis to consider these concepts in any depth, but like NBS, the breadth of the framing of QoL has led to criticism that it is a 'catchword' for different notions of a good life based on opportunities or liveability and outcomes or the utility of life (Veenhoven, 2014) that has led to confusion and interchangeable use across policy, research and practice (Marin, 2014; Martinez et al., 2021).

In contrast to Veenhoven (2014) other scholars (Galloway, 2006; Shafer et al., 2000; El Din et al., 2013; Murgas, 2016) argue QoL is a networked concept with dynamic interactions between objective (such as income, housing, employment, the micro-environment), subjective life conditions (family structure, social networks) and the degree of congruence or dissonance that people have with their everyday living environment (including the natural environment) influenced by socio-political factors, equitability of access of resources and principles of justice. Mensah (2014) later constructed a conceptual model Figure 2.1) based on the Millennium Ecosystem Assessment Report (2005) to illustrate the connections between social, economic, and environmental benefits of greenspaces to human well-being and quality of life. However, this model does not consider the capability of urban inhabitants to access, or use these resources, including the influence of the institutional processes on the governance or management of greenspace. Furthermore, Delhey (2014) argue inequalities or an uneven distribution of QoL may occur across different groups if exploitation or uneven power relations influences urban inhabitants' ability to access resources. Hence, it is useful to draw on Sen (1982, 1993), who defined the ability of a person to do or be certain things as 'functioning's' and the freedom of opportunity that a person must influence such functioning's in life. Functioning's are referred to as the capacity to influence lifestyles that constitute the capacity lives or lifestyles. Blecic et al., (2013) and Sirgy et al., (2011) argue that evaluation of the

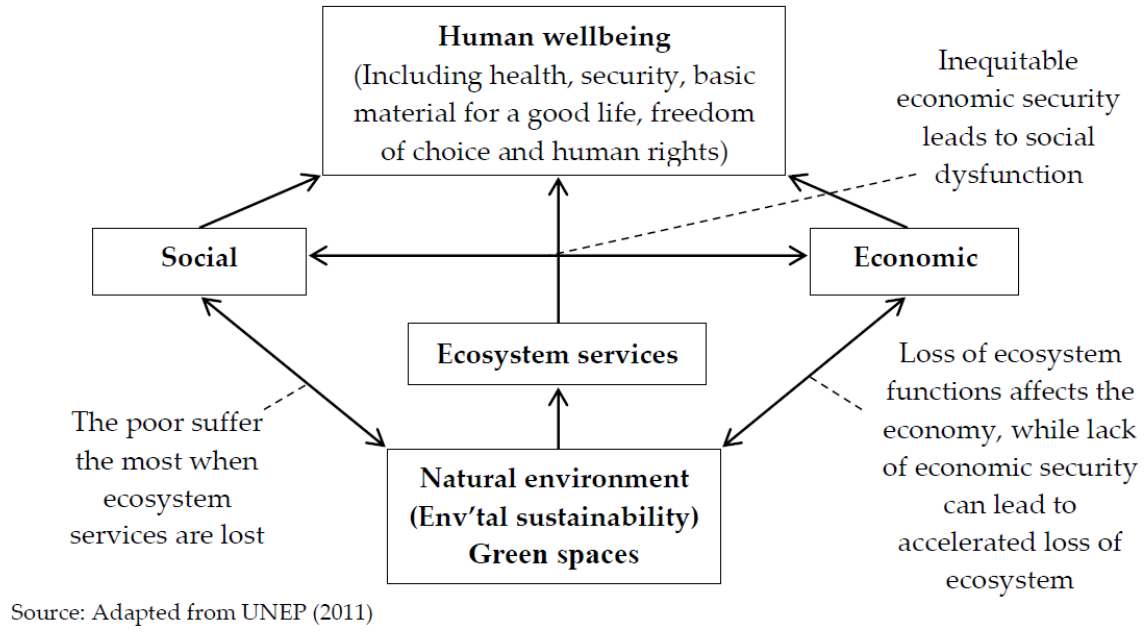

Figure 2-1 Conceptual linkages between the quality of life and urban greenspace (source: Mensah, 2016).

influence of NBS on QoL from a capability approach means to verify how and if urban inhabitants can exercise the ability (i.e. exercise internal power) to be able to engage with NBS and if they have the 'opportunity' (i.e. external conditions) permit people to do so. Hence, the thesis defined QoL of urban inhabitants as a networked relationship between different socio-economic conditions, socio-cultural and socio-political processes, the urban fabric (including urban green space) and their characteristics, and the ability and opportunity of urban inhabitants to access those resources through the governance and management of NBS. Drawing on this conceptualisation of NBS, Chapter 4 examines how the distribution of different aspects of QoL relates to different types of ecological domains and types of ecosystem services that provide resources that could improve QoL. In doing so, this chapter also begins to unpack the role of different institutional conditions on providing urban inhabitants opportunities to access these goods.

2.3.2 Measures of Quality of Life

Scholars describe two basic approaches to measure QoL of people living in cities that use quantitative indicators derived from aggregated spatial data and subjective assessments of QoL (see Maran et al., 2005; Pacione, 1990, 2003; Mensah et al., 2016). Quantitative (also known as objective) indicators include poverty, education attainment, life expectancy, employment, and unemployment rates (Pacione, 1990, 2003). These indicators are perceived (or subjective) measures that are often more easily defined and quantified comparisons across countries, regions, cities, and demographic sectors and time. In comparison, subjective indicators of QoL are more challenging to define and often criticised for being impractical. However, these indicators measure individual perceptions of the experience of life and well-being, including emotional reactions to life events, sense of fulfilment and satisfaction with work or personal relationships (Pacione, 1990, 2003; Murgas, 2016; Marans, 2003, 2005; Marans and Stimson, 2011). Lack of available data across different scales is one of the main barriers to research using subjective indicators (Diener and Suh, 1997). However, Pacione (2003) argues that quantitative measures of QoL can be used as a surrogate for subjective measures because they are closely related and influence perceptions of QoL (Marans and Simpson, 2011; Morris and Carstairs, 1991). In view of this evidence and the lack of availability of subjective indicators of QoL on a pan-European basis, Chapter 4 utilises quantitative indicators published by the Urban Audit, which represent different aspects of QoL. The indicators that are used in Chapter 4 are discussed in the Methodology (Chapter 3).

Given the multidimensional nature of QoL some scholars (Michalos, 2014; Land and Michalos, 2015; OEDC 2004) argue that life quality cannot be captured in a single indicator. These authors argue QoL should be represented by a composite indicator that represents material and subjective the dimensions of QoL as well as the geographical or environmental setting in the city, neighbourhood or dwelling which influences QoL. Table 2-1 evaluates quantitative, subjective and composite measures, briefly describing these indicators' examples and their advantages and limitations. Investigation into the availability of quantitative and subjective indicators for QoL across different European cities reveals there are no pan-European datasets that consist of subjective measures of QoL for each city that could be utilised in this study.

Hence, given the lack of subjective data and the interrelationship between objective and subjective measures, it is helpful to consider how composite indices may be created using objective measures of QoL. Studies have shown that Socio-Economic Position (SEP) is closely related to QoL since the social determinants that cause ill-health are associated with a decline in life quality (Choi et al., 2015; Henriques et al., 2020; Read et al., 2014; Blane et al., 2007). Thus, in the next section, critical debates on the concept of SEP, its influence on the determinants of urban health and QoL are reviewed.

	Quality of Life Indicators		
	Objective	**Subjective**	**Composite**
Description	Structural indicator on quality of life covering a full range of issues include such as education attainment, life expectancy, employment and unemployment rates and obesity More readily available and easier to measure. They can be used as surrogate for subjective indicators since they closely relate to perceived quality of life indicators (Marans and Stimson, 2011; Morris and Carstairs, 1991).	Measures and evaluations of individual perceptions of the experience of life and well-being. They include emotional reactions to life events, sense of fulfilment and satisfaction with work or personal relationships (Pacione, 2003)	Derived from different attributes of the environmental setting to be combined or weighted to create an index representative of the concept that is being measured (OEDC, 2004)

Limitations	Do not convey the subjective measures such as differing perceptions of a place or setting and the influence on quality of life. Though they are thought of as objects, they can be fraught with measurement problems. Approach to selecting indicators for measurement maybe adhoc and lack theoretical rigor. Indicators may be influenced by subjective decisions about measurement.	Complex, difficult to define and measure. Often criticised for being impractical, but they can provide a more accurate measure of each person's differing perceptions about that setting and its characteristics (Marans, 2003; Marans and Stimson, 2011). Don't capture structural measures about the quality of the geographical or environmental setting in the city, neighbourhood or dwelling. Where indicators are available on a pan-European basis, they are often based on a small sample or that is used to create an indicator that is representative of national scales. Often unavailable at city-scale or neighbourhood level analysis.	Exclude some measures that relate to deprivation and influence quality of life (Messer et al., 2006). Often very complex. Changes made administrative boundaries, survey questions, or political influences on weights applied to individual variable domains may lead to concept misrepresenting quality of life (Deas et al., 2004; Norman, 2010) Lack of pan-European indicators. For example the Index of Multiple Deprivation is available in the UK but not available for European cities.
Examples	Urban Audit Census data	European Quality of Life Survey and European Household Panel Survey. Data only available for selected European cities.	Examples include work by Townsend (1987) and Carstairs (1995) to create composite indicators using contextual (ecological) measures of socio-economic status. These were used as a proxy to describe and quantify deprivation and demonstrate its relationship with population health.et al.,

Table 2-1 Critical review of quality of life indicators available from open sources of data.

2.4 Socio-economic position

2.4.1 What is Socio-Economic Position (SEP)?

SEP is an aggregate concept that is indicative of people's position within the social hierarchy of society, their likelihood of being exposed to harmful effects of urbanisation or climate change, or capability to resources that might mediate these effects or enhance health (Lynch and Kaplan, 2000; Marmot, 2010). Galobardes et al., (2007) define SEP as "*socially derived economic factors that influence what positions individuals or groups within the multi-stratified structure of society*" (pp.23). This definition describes material or social resources and assets (including income and education) and prestige-based assets. Class position also plays a role in an individual's ability to access resources, services, or knowledge (Krieger et al., 1997). According to Lynch and Kaplan (2000) and Salmond et al., (2006), SEP is concerned with the conditions that people experience that influence their position in society. These factors influence the likelihood that they may be exposed to the ill-health effects of climate change or urbanisation or may impede access to resources that could mediate these effects. Factors such as resource ownership and control, cultural and behavioural factors and power differentials may also be influential (Salmond et al., 2006).

Hence, SEP and QoL are closely related. However, similarly to QoL, there has been criticism over its interchangeable use with other concepts (such as social class, social stratification, and socio-economic status) despite being measured and conceptually different (Rubin et al., 2014; Galobardes et al., 2007). In contrast, Krieger (1997) argues conceptual confusion is due to overlap in different measures that represent access to resources and prestige-based assets across each of these concepts. For example, Townsend (1987) states, "*deprivation takes many different forms in every known society. People can be said to be deprived if they lack the types of diet, clothing, housing, household facilities, fuel and environmental, educational, working and social conditions, activities or facilities which are customary, or at least widely encouraged and approved, in the societies to which they belong*." (p.126). Townsend's definition focuses on the living standards of individuals. However, it is also closely related to SEP (due to the relationship between material and social or relational dimensions of living

standards), blurring the distinction between resource and prestige. Hence, while paying attention to these critiques, Chapter 5 draws on the concept of SEP to examine the interaction between different social and economic conditions that influence inequality in cities and different characteristics of NBS that could provide or help facilitate access to resources, goods or services that could improve QoL.

Theories that underpin SEP owe their origins to major sociological traditions of Marx and Weber. According to the Marxian tradition, SEP is determined by an individual's social relationships with different 'means of production' (Lynch and Kaplan, 2000) or subjective class consciousness (Weeks and Leavitt, 2017). Critics argue that Marx's three-dimensional portrayal of the class structure of 'wage-labours, capitalists and landlords (Marx, 1973: reprinted in Levine, 2006, pp.47) is too simplistic and purely structural (see Galbardes et al., 2007; Grusky et al., 2014) leading Weber to argue social stratification occurs along many dimensions creating different groups that share a similar position with respect to life chances influenced by utilising education, skills and attributes for social advantage in the marketplace. Weber's ideas underpin the use of education, occupation, and income as measures of these dimensions (Galobardes et al., 2007; Grusky et al., 2014). More recently, Weeks and Leavitt (2017) suggest occupation or professional position can be used to represent prestige, social class or status differences due to the association between occupation and social stratification across individuals or groups in society. In view of this evidence, like Galobardes et al., (2007), this thesis draws on this conceptualisation of SEP: access to resources associated with different modes of production stratified by class, status, and power lead to the uneven distribution of resources and skills.

2.5 Indicators of SEP

According to Rubin et al., (2014) and Galobardes et al., (2004), there is no single preferred indicator of SEP. However, the choice of indicator used in the analysis should be based on the dimension of socio-economic stratification, health outcome or stage of life course being researched. Education attainment and occupation are frequently used as indicators of SEP in epidemiological studies. Education captures opportunities for urban inhabitants to access

knowledge-related assets. It can also be used as a proxy measure of income since it is a strong determinant of future employment and income (Galobardes et al., 2007; Lynch and Kaplan, 2000). Lack of formal qualifications is an essential feature of deprivation and driver in inter-generational socio-economic mobility.

In contrast, occupation can reflect a person's place in society related to their social standing, income and intellect. However, social meanings related to different types of occupation have changed substantially across different economies, changing the pattern of distribution of different types of employment across the economically active population (Purcell, 2018; Galobordes et al., 2004, 2007; Wegner, 1991). Income is also an important indicator of access to material resources (such as food or housing) and can influence self-esteem and social standing within communities. Often based on median or average measures of household income, but like some indicators of occupation excludes those social groups at risk of the consequences of social stratification (Salmond et al., 2006). Hence, the thesis will draw on education and income indicators published in the Urban Audit and European Social Living Condition Indicators for occupation class to represent education attainment and occupation-related dimensions of SEP (Eurostat, 2017).

However, these scholars also highlight that some occupation classification schemes have not been updated, changing the ratio of different occupation classes across schemes and how they relate to measures of SEP (Purcell, 2018; Galobordes et al., 2004, 2007; Wegner, 1991). For example, Purcell (2018) suggest the occupation classes included in these schemes do not reflect the emergence of informal economies, unpaid domestic and caring roles and other forms of unpaid employment that vary based on age, ethnicity, and gender. Hence, to include these groups in SEP analysis, the thesis draws on indicators that represent urban inhabitants at risk of severe deprivation or poverty due to receiving welfare support or limited working hours.

2.5.1 Composite or Area Measures of SEP

Area-level indicators (or ecological measures) of SEP, also known as measures of deprivation, can also be obtained by individual aggregating measures to create composite indices. Due to the lack of availability of individual data across different administrative boundaries, these measures are often used as a proxy by researchers to quantify deprivation and demonstrate its relationship with population health. Early examples include the Townsend Material Deprivation Score comprised four standardised variables: unemployment, overcrowding, not owning a car or home and the Carstairs indices, which substituted low class for non-home ownership (Harvard et al., 2008; Galobardes, 2006) (see Table 2-1). Messer et al., (2006) are critical of area-level indicators indices since they do not include deprivation factors contributing to QoL. Jordon et al., (2004) suggest that work on the UK Index of Multiple Deprivation has attempted to address these concerns by incorporating six indicators: income, employment, health deprivation and disability, education, skills and training, housing and geographical access (straight line distance) to service into one single composite measure of deprivation. However, Deas et al., (2004) are critical of the complexity of multidimensional indices of deprivation due to the double-counting of some indicators and the influence of socio-political factors on weightings rather than technical justification.

Despite this critique, other studies have created area-level indices such as the European Deprivation Index for France and Portugal developed by (Pornet et al., (2012) and Ribeiro et al., (2017) using the definition of deprivation developed by Townsend. These scholars created a measure of deprivation using logistic regression models based on EU-SILC and census tract data. Earlier studies deployed Principal Component Analysis and factor analysis to create socio-demographic indices to validate statistical models (Messer et al., 2006; Harvard et al., 2008). Scholars (Norman, 2010; Fieldhouse and Tye, 1996) are critical of city-wide indices for deprivation, arguing that ecological fallacy could lead to misinterpretation of results and assumption that each citizen and household is deprived. In contrast, early research by Morris and Carstairs (1991) argues that indices that contain fewer indicators (such as the Townsend Index) achieve similar area-level scores to more complex indices and may be used as a proxy for socio-economic disadvantage. However, Oakes (2004) urges caution since while area-level indicators are a useful proxy, they are likely to underestimate the association between SEP and

health due to the effects of neighbourhood contexts. Given this evidence, the thesis adopts the approach applied by Messer and Harvard to create a city-wide index for SEP while noting the work of Morris Carstairs and Oakes. Chapter 3 elaborates on the methodology applied to this work, while section 2.7 sets out the rationale for choosing the city as the analysis level.

2.6 Quality of Life, Health and NBS

2.6.1 Nexus between QoL, differences in health and NBS

The ways of urban life, living and social conditions, socio-economic factors and changing environmental conditions that influence QoL also interact to shape differences in patterns of inequity health within and between cities (Friel et al., 2011; Land and Michalos, 2015; Marmot et al., 2021, 2010, 2008; Wilkinson and Pickett, 2018). In other studies, scholars (see Fudge et al., 2020; Anenberg et al., 2020; Prüss-Ustün et al., 2019; WHO, 2016, 2020) highlight many of the health challenges that have emerged in cities are not only the result of poor social and economic conditions, but also the synergist effects of climate change and urbanisation on poor health and the poor urban planning and management in cities. Furthermore, while the concept of health is not central to the framing of NBS per se, there is a growing body of research that suggests that green and blue space provided by these interventions could help to mediate some of these health risks, especially in deprived communities that lack access to greenspace (for a review see Lovell et al., 2018; Mitchell and Popham, 2008; Maas, et al., 2009; Mitchell et al., 2015; Ward Thompson et al., 2013; Roe et al., 2013).

Despite this growing body of evidence, Van den Bosch (2017) argues that the framing of public health outcomes is less prominent within the conceptual framework of NBS than other environmental, social, and economic benefits due to insufficient consideration of the complex, intimate relationship between environment and public health. Dumitru et al., (2020) also suggest that this may be due to a scarcity of specific studies that examine the influence of the different characteristics of NBS on health, leading to the knowledge of multiple benefits becoming fragmented and uncertainty about the relationship due to lack of causal evidence (Van de Berg et al., 2015).

Other scholars (Rutter et al., 2017; Alberti et al., 2018; Curtis, 2010) suggest the lack of availability of evidence may be due to failure to conceptualise the impact of these interventions within the context of complex systems operating at different geographical scales. Alberti et al., (2016) and Curtis (2010) argue that studies often focus on linear approaches to modelling cause and effect without disentangling how multiple agents and components interact across different scales to influence the emergence of access or use of resources that influence urban health and the persistence of health inequalities. Scholars (Rutter et al., 2017; Egan et al., 2019; Pearce, 2018; Roux et al., 2011) also argue framing the nexus between urbanisation, climate change and public health within the context of complex systems is not only important for understanding how different components of socio-ecological systems interconnect and influence each other, but also important for the design and development of effective policy responses for cities. Given the lack of studies on the relationship between health and NBS, this thesis also investigates the influence of different types of NBS and the ecosystems services on health outcomes (Chapter 6). In addition, it will also ask how the governance and management of NBS influence the ability or capacity of urban inhabitants to use or access these resources. Hence, the next section of the literature review examines the concept of health.

2.7 Definition of health

Health is a complex, socially constructed concept that is open to different interpretations and definitions (Curtis, 2004; Gastell and Elliott, 2014). It is described as a state of physical, mental, and social well-being, and a resource for everyday life (WHO, 1948) that allows people to function and participate in activities as members of society (McCartney et al., 2019) (section 2.3.1 outlines conceptual linkage with QoL). Gastell and Elliot (2014) also suggest that the definition of health should account for the availability of personal and societal resources that allow us to cope with or manage our health or alter our environment. This contrasts with the definition of inequity in health which relates to unfair differences in health due to lack of resources and is an issue of social injustice (Graham, 2009). The distribution of resources that could improve the quality of Graham (2009) conceptualised unequal health as 'systematic differences in the health of people that occupy different positions in society (Graham, 2009, p3) that are often associated with differences in SEP, ethnicity and gender that are socially

produced, unfair and unjust (Bambra, 2016; Whitehead, 2007). In light of this evidence and the relationship between health, SEP and notions of justice that influence QoL of urban inhabitants, this thesis adopts the definition of unequal health developed by Graham (2009).

Differences in health can worsen or improve different aspects of urban life, such as changes to the physical built environment, social conditions, socio-economic conditions, environmental conditions, all interact and may be exacerbated by the effects of climate change (Friel et al., 2011; Bonner, 2017). Scholars (Galobardes et al., 2006; Marmot, 2006; CSDH, 2008; Solar and Urwin, 2010; Lynch and Kaplan, 2000) argue that the unequal distribution of resources among different social groups due to structural and institutional processes leads to differences socio-economic conditions that influence and lead to differences in health. Different social and economic circumstances influence health are the social determinants of health (SDOH). It could be argued that NBS are a determinant of health (Lovell et al., 2018) since scholars claim that they not only provide resources (such as urban greenspace or access to ecosystems services) that can improve life quality. However, interconnections between governance, participation, citizen involvement and power differentials can interact to influence the ability and capacity of urban inhabitants to access resources that could improve health.

Similarly, to QoL, the SDOH is a complex and multifaceted concept with a range of models and theoretical frameworks to explain what they are, how they operate and how they can be addressed. These models include life-course models, theories of materialism and neomaterialism, psychosocial explanations of inequality and cultural capital (see Dahlgred and Whitehead, 1992; Bambra, 2016; Lucyk and McLaren, 2017; Mackenbach, 2012 for a review). It is not the intention of the thesis to review these models, but Bambra (2016) argues that no one theory explains the complexity of interactions of underlying causes that influence health. However, the emergence of the SDOH suggests thinking is moving beyond a health model and lifestyle approach to understanding the upstream causes of ill health and how social, economic and political environments in which we live and work influence ill health within different socio-economic groups (Raphael, 2009). Regidor (2006) argues that SDOH further blurred understanding of social inequalities in health, creating further 'conceptual ambiguity' since it is

impossible to distinguish if health inequalities are based on 'differences in health' or SDOH that are associated with SEP.

2.8 NBS as a determinant of health

In cities, the built and natural environment is an important determinant of health, particularly among disadvantaged groups by relative poverty, unemployment, low status, gender, ethnicity, and disability (WHO, 2012). A recent review by Lovell et al., (2018) suggests that green space provided by NBS is a key determinant of health in urban areas influencing physical and mental health. Studies by Mitchel and Popham (2008), Mass et al., (2009) and Brown et al., (2016, 2018) found a reduction in all-cause and circulatory disease mortality and prevalence of cardiovascular, musculoskeletal, respiratory, or other diseases among populations with low socio-economic status, but greater access to green space. Mitchell et al., (2015) suggest NBS may influence health is through their 'equigenic' properties provided by salutogenic resources that reduce the effect of environmental inequalities such as air pollution, climate change and other hazards (Jennings et al., 2012). Other studies support these claims suggesting that contact with nature in urban settings can help to can build capacity by improving physiological health through increased physical activity and provide restorative effects that reduce levels of depression, anxiety, and psychological distress (Hartig et al., 1991; 2014; Mass et al., 2009, Pope et al., 2015; Mitchel, 2013: Kaplan, 1995, Chloe et al., 2020). In other studies, scholars suggest that mitigation takes place by improving relaxation and restoring mental health, social capital and cohesion, and the functioning of the immune system (WHO, 2017, Hartig at el., 2014; Kabisch et al., 2017; Mitchell and Popham, 2008). Three domains of biopsychosocial pathways have been proposed to explain the health benefits: i) restoring capabilities, ii) building capacity by enhanced physical activity, improved fitness and reduced obesity or diabetes, iii) reducing harm through mitigation by acting as a buffer against noise pollution, exposure to air pollution and reduce the impact of the urban heat island effect or flooding (Hartig at el. 2014; Fairburn et al., 2019; Markevych et al., 2017; Dalton et al., 2016).

Despite growing evidence of the relationship between greenspace provided by NBS and health, the pathways linking SEP, heath, QoL and NBS are complex and multifaceted, with those that

generate benefits remaining unclear (Markevych et al., 2017). Scholars NBS could prevent the 'upstream' causes of health inequality by mediating risks to urban health associated with urbanisation and climate change, particularly in low-income and deprived communities (Maas et al., 2009; Ward Thompson et al., 2013; Roe et al., 2013; Mitchel and Popham, 2008; Mitchel et al., 2015). However, inequitable distribution of interventions is a prominent barrier to addressing urban health disparities across groups of differing SEP (Kuta et al., 2014; Coomber et al., 2008), leading to Kabisch and Van den Bosch (2017) to conclude that NBS is not being targeted at communities that need them most. Other studies also suggest that access to urban greenspace provided by interventions such as NBS is stratified based on income, ethno-racial characteristics, age, gender and (dis)ability (Jennings et al., 2016; Wolch et al., 2014) with racial minority or groups with lower socio-economic status experiencing poorer provision and quality greenspace than more affluent citizens (Kuta et al., 2014; Kabisch and van de Bosch, 2017). Several studies (Crawford et al., 2008; Koohsari, 2011; Dadvand et al., 2014) also suggest urban inhabitants with greater access to greenspace are more affluent and hence, vulnerable groups (such as including the elderly, children, and those living in socially and economically deprived areas) are at greater risk of exposure to the ill-health effects of climate change and urbanisation (Kabisch and van den Bosch, 2017; Richardson et al., 2013; Martuzzi et al., 2013) creating issues of environmental justice. Hence, this thesis will explore how the distribution of the key characteristics of NBS relate to different social and economic conditions that determine poor health (Chapter 4) and the extent to which different vulnerable groups are engaged with different institutional processes that provide opportunities or influence the ability and capacity of vulnerable urban inhabitants to access resources that could improve health (Chapter 5). Evidence of a relationship between different types of NBS, the ecosystems services they create and the institutional processes that they adopt, and health outcomes will be addressed in Chapter 6.

2.9 The relationship between NBS, health and gender

Scholars (Stafford et al., 2005; WHO 2014; Bird and Rieker 2008) suggest physiological differences in vulnerability to disease, the dose-response and the way in which men and women perceive their environment differently may influence the relationship between gender, climate

and health. For example, more recent research by Fairburn et al., (2019), Cushing and Sorensen (2021) and Payne (2016) suggests the effects of temperate and heat interact with social and physiological differences between men and women to amplify gender-based risks of exposure and vulnerability to climate change. Further more, Cushing et al. (2018) argue that health risks associated with exposure pathways between men and women can differ substantially influenced by gender-based differences in culture, ethnicity and socio-economic circumstances as well as physiological differences. This has led some scholars to suggest that gender, age, and ethnicity may also influence the dose-effect relationship between NBS and health (Fairburn et al., 2019; Cushing and Sorensen, 2021; Payne, 2016; Markevych et al., 2017). However, the evidence is not conclusive, hampered by a lack of gender-specific data of the impact of climate on health (Sorensen et al. 2018; van Daalen et al. 2020) and interchangeable use of gender-based and sex-linked biological measures in epidemiological and health research (Spring et al., 2012; Krieger, 2003). Despite being different constructs (Chapter 2), Krieger (2003) argue sex-linked biological and socially constructed gender-based measures can be distinct or synergistically linked depending on the study population. Hence, in Chapter 6 the thesis begins to explore the relationship between gender-related health outcomes and different types of NBS, the ecosystems services they create and different institutional conditions that influence the governance and management of NBS.

2.10 Relationship between NBS, QoL and Environment Justice

Scholars argue that addressing inequalities in green space can create an urban green space paradox worsening social, economic and health inequalities. Several studies (Goodling et al., 2014; Checker et al., 2011; Anguelovski et al., 2017) suggest that creation or improvements in UGS does not always improve QoL but can alter the social structure culture and pattern of consumption of the community (Gould and Lewis, 2012, 2018; Wolch et al., 2014; Cole et al., 2017). This process, known as Ecological Gentrification (Dooling, 2009: Anguelovski, et al., 2017) or Green Gentrification (Gould and Lewis, 2012: Pearse and Anguelovski, 2016), results in 'residential sorting' where long-term residents who are socially and economically vulnerable are displaced by more wealthy, affluent citizens attracted by the ‘green lifestyle’ leading to rental and property value increases displace long-term residents, particularly those who are

socially and economically vulnerable (Cole et al., 2017; Anguelovski et al., 2017; Rigolon and Nemeth, 2018). Others are critical of city municipalities' role, mainly, environmental planners have played in gentrification. Anguelovski (2015) and Lees et al., (2012) suggest urban environmental improvements have been used as a 'sugar coated' strategy to revitalise undesirable neighbourhoods and attract investment by marketing the opportunity of a 'rent gap' (Smith, 2008) or/and potential capital returns (Cole et al., 2017; Angueloski et al., 2017). Rigiton and Nemeth (2018) suggest that municipal and other influential actors use sustainability discourse to depoliticise planning processes to minimise or deflect opposition and devolve power delegating project development, delivery, and maintenance to non-profit organisations to reduce accountability financial burdens.

2.11 Conceptualisation of Justice

The word justice can be used to describe a host of different actions, regulations, and conditions. It is a multifaceted concept with no one theory encompassing all different discourses of justice that may be applied simultaneously to individuals, groups and communities (Scholsberg, 2008; Sen, 2011). In simplest terms, it is concerned with what people are due and questions of power that influence the primary distribution of social goods, liberty, opportunity, income, and wealth.

Different theoretical conceptualisations of notions of justice have been the subject of moral and political philosophy for millennia. Plato considered justice to be a virtue that brings harmony to the soul, while Aristotle defined justice according to matters of punishment, compensation or proportional equity, the distribution of social benefits. In contrast, Kant (1999) understood justice as a subset of duties towards others that can be legally enforced, and Cohen and Greenberg (1982) and Hobbes (1947) viewed justice as artificial arising from disputes over resources and goods in short supply. It is not the intention in this thesis to review each of these different theories of justice or how they have evolved but to examine how different discourses of justice relate to the distribution of NBS. Hence, the thesis draws on the definition of environmental justice developed by this study adopts the definition of environmental justice developed by Hollifield et al., (2018), which defines environmental justice as a multidimensional concept that encompasses distribution, procedural participatory, justice as

recognition and justice as capabilities as well as the interactions between each of these dimensions. The next section of the literature review examines the debates surrounding these justice dimensions and how they relate to NBS.

2.12 Conceptual linkages between distributive, recognition, procedural injustice and justice as capability

Scholsberg (2008) suggests that justice discourse is a balance of interlinked dimensions of distribution, recognition and participatory justice and justice as capability. Thus, distributive aspects of environmental justice are relevant to how the differing types of ecological domains and ecosystem services that characteristics of NBS are distributed, while the interconnection between governance, participation and citizen involvement can influence participatory and recognition justice, but also justice as capability.

To begin, it is helpful to consider theories of distributive justice. Like the concept of justice, distributive justice is a pluralistic concept concerned with how harms and benefits are distributed and experienced (Scholsberg, 2008). Rawls' (1971) theory of justice is 'justice as fairness' where the distribution of political, social, and economic, goods and bads, is determined by society's basic structure. The scholar depicts justice as an interconnected system of rules and practices that are 'just' which influence people throughout the life course and determine their capacity to exercise fundamental rights to access resources through agency (Rawls, 1999; Sen, 2014). Rawls suggests that we stand behind a 'veil of ignorance' where individuals are unaware of their place in the social hierarchy, strengths, or weaknesses. In this imaginary, Rawls argues that social and economic inequality benefits all of society, including the least advantaged, and everyone would have the same political rights (Freeman, 2003; Scholsberg, 2008). His theory aims to advance two principles of justice: the fair equality of opportunity principle and the difference principle. The first principle asserts that each person in society has an equal right to fundamental liberties. While the second posits that social and economic inequalities are only acceptable if there is fair and equal opportunity to access goods and services across society. The later principal also asserts that differential treatment of some groups within society is acceptable, but only if the least advantaged in society benefit. Critics

(see Barry 2005; Bertram 2004; Young, 2011) argue Rawls universal, cooperative scheme is idealistic and untenable. These scholars suggest that individuals and actors governing social, political, and economic institutions will make choices based on their own needs or needs of the organisations they represent rather than the universal needs of society.

However, some scholars (Engets and Marx, 1971: Young 2011 and Freeman 2003) were highly critical of Rawls' notion of 'least advantaged', suggesting that it obscures inequality across different social groups. To address these issues, Barry (2005) proposes the principle of 'justice as impartiality' where a procedural approach to the distribution of goods and rights while remaining impartial to different notions of a good life (Barry, 2001, 2005: Schlosberg, 2008). Young (2011) and Fraser (2011) critiqued these conceptualisations of justice. Young argues that Rawls' theory does not consider the underlying social, cultural, symbolic, and institutional conditions that influence inequitable distribution (Scholsberg, 2004). Hence, Young (2011) defines social justice within the context of the moral distribution of social benefits and burdens that include material and non-material resources (such as rights, opportunity, power and self-respect) across society. Young posits that lack of recognition combined with structural and institutional conditions that delimit people's lives leads to oppression and domination, restricting denying individuals the opportunity to develop and exercise their capabilities access to resources (Young, 2011; Scholsberg, 2004). Hence, in light of this evidence, the thesis draws Rawls and Youngs to examine how the differing characteristics of NBS are distributed across the different regions of Europe (see section 2.6.1) and how these trends relate to different social and economic conditions influence QoL (Chapter 4).

In contrast, Fraser's conceptualisation of justice requires attention to the underlying conditions that create distribution and recognition injustice. Both Young and Fraser suggest a direct link between lack of recognition or respect and participation of civic or institutional processes within broader communities. In response to these critiques, Rawls's counter critique argues that justice as recognition is not a distinct dimension since recognition and respect are inherent preconditions to distributive justice. However, Schlosberg suggests Rawls's claim is flawed since distribution justice focuses on the state's role as arbitrator, and recognition cannot simply be distributed since it is a relationship and social norm (Scholsberg, 2004).

Sen (1992) is also critical of Rawls; he suggests that justice is not only influenced by interactions between society but also structural and institutional processes. Sen argues that the ability of individuals to convert their basic capabilities into functioning's to maintain essential needs (such as access to housing, avoiding starvation or poverty) also influences justice. The concept of capability captures the freedom that an individual needs to pursue to achieve goals for well-being and other forms of agency on internal conditions (for example, being free from illness) and access to external circumstances that enable an individual to exercise this capability (Sen, 1985, 1992; Holland, 2017). To explore how the distribution of different characteristics of NBS influence provision of resources and opportunities to develop capabilities to use or access these resources, Chapter 5 asks how changing framings that underpin NBS have influenced the interconnection between governance, participation and citizen involvement and the relationship with SEP, social vulnerability, and adverse health outcomes.

2.13 Politics of recognition and Participatory Parity

In the context of environmental justice, Schlosberg argues that recognition as justice is a central concern of justice. It is also useful to consider dualism perspectives of justice as redistribution and recognition referred to as the "politics of recognition". In this context, individuals may suffer from both distributive and recognition injustice due to the two-dimensional relationship between politics of misrecognition or maldistribution where either dimension is the route cause of injustice but is reinforced by co-existence with the other (Fraser and Honneth, 2003). Young and Fraser argue that difference blind politics of redistribution can reinforce distributive injustices due to pre-existing structural inequalities by misrecognising the diverse nature of social group differences. In unpacking the relationship between distributive and recognition injustice, it is also helpful to consider the notion of 'participatory parity' developed by Fraser and Honneth (2003). Fraser argues that for different social groups to interact with each other, resources and opportunities for participation should be equally distributed and open to all social groups so as to prevent exclusion, particularly of marginalised groups. Fraser and Honneth differ in their understanding of the impact of justice as recognition. Fraser argues that Honneth's conception of recognition is flawed because it focuses on the impact of lack of recognition on an individual's mental well-being in terms of disrespect and self-realisation. Honneth argues

that recognition should be based on psychology and status since they are not mutually exclusive. Distributive theorists such as Rawls argue recognition is inherent and assumed while respect is a good that is explicitly acknowledged within distributive theory. Young argues that recognition is not a service or a good to be distributed but a relationship embedded in social practice. Scholsberg (2008) also argues there is a lack of evidence to support the claim that recognition is distributive justice since the status of unrecognised groups needs to be recognised before resources are distributed by recognising the distribution of existing inequalities and the effect of institutional structures and practices. Hence, Fraser posits that a trivalent understanding of justice is needed that integrates justice as distribution, recognition, and participation. Thus, in Chapter 5, the thesis explores different framings that relate to the externalisation of nature or equal benefit of NBS for people and nature framing are influenced by the politics of recognition or participatory parity and in doing so, ask to what extent do interactions between governance, participation and citizen involvement relate to factors that influence recognition or participatory injustice.

2.14 Environmental justice and environmental inequality

While NBS are typically framed as a public good, research suggests some groups who live in communities being rejuvenated by NBS are often excluded and made invisible by urban elites responsible for framing these interventions (Calderon et al., 2021; Torres et al., *submitted*; Anguelovski et al., 2018; Cole et al., 2017). Consequently, Toxopeus et al., (2020) argue that socio-political processes at play among actors involved in the governance and management of NBS may inadvertently create issues of environmental injustice.

Scholars such as Scholsberg (2007) and Walker (2012) argue that the principles of environmental justice are pluralistic and deeply rooted in the economic structure of society but are mainly concerned with the distributive justice paradigm. Based on Scholsberg (2007) and Rawls (1971), this thesis defines distributive justice as relating to the equitable distribution of benefits by different types of ecological domains created by NBS and the ecosystems services that they create and the extent to which their benefits can be accessed by society. Fraser and Honneth (2003) argue that the distributive justice paradigm also includes the underlying

processes that construct and influence the distribution, such as equity, recognition, and participation. Hence, this thesis defined procedural justice as the extent to which different actors and communities in particular marginalised and disadvantaged groups, are included in the decision making processes adopted in the governance and management of NBS. Nussbaum and Sen (1992) argue the extent to which different groups of actors and members of civic society are involved in institutional processes or can participate in these processes to take advantage of goods and resources provided by NBS and their level of influence overlaps with both procedural and recognition injustice. Hence, the thesis adopts the definition of recognition injustice based on Scholsberg (2007) and Fraser and Honneth (2003), which defines recognitional justice as the recognition or respect given to different actors or societal groups during decision-making and considers the processes that construct that distribution, such as the ability of society to participate.

Scholars argue that environmental justice also relates to the intersection between environmental quality, deprivation, environmental rights, and more structural questions that focus on social equality, that is the unequal distribution of power and resources and environmental burdens (Pellow, 2000; Aygeman et al., 2003). Thus, environmental justice and environmental inequality can co-occur when different stakeholders struggle to access scarce resources within the political economy, and the benefits or costs of resources are delivered unevenly. Hence, this thesis adopts the definition of environmental developed by Hollifield et al., (2018), which defines environmental justice as a multidimensional concept that encompasses distribution, procedural participatory, justice as recognition and justice as capabilities and the interactions between each of these dimensions.

2.15 Cities and Regions: contested concepts or units of analysis?

This section of the literature review attends to key conceptual debates that relate to the units of analyse adopted in this thesis.

2.15.1 The Region

The region is a central but contested concept in geography. Regional geography focuses on territorial or absolute boundaries and examines the diversity and organisation of nature and human aspects as an integrative framework (Paasi, 2020). However, throughout the 1950's undertaking a regional study was thought to be a basic, descriptive exercise that privileged some regions above others, glossed over swathes of political, cultural and historical landscapes and simplified or theoretically reduced people and places (Jones, 2017; Riding, 2018). A critical turn in human geography led to the transition of regional geography to the reconstruction 'new regional geography' in the 1980s (Thrift, 1990). Here the focus of study evolved to examine the socio-cultural construction of regions as constituted different forms of agency and power relations, drawing on Marxism, humanistic geography, and practice theories (Paasi, 2020; Riding, 2018).

Subsequently, the territorial, politically charged nature of economic development and geographies of globalisation and regional development overtook these developments, leading geographers to think about regions as "crucibles for economic success and demographic legitimacy" (Jones, 2017, pp. 3). Paasi (2020) argues that geographers view regions not as unique isolated entities, but regions are relational and temporary assemblages that frame processes of institutionalisation and transformation of regions. This resituated the regional within a multidimensional approach that allowed interconnected roles of the region, the state, the city and the local on socio-spatial relations of economics, governance and politics and the region to be examined (Riding, 2018). Paasi (2020) argue new regional geography does not privilege any specific scale but utilises the 'region' as a tool to analyse processes that take place in, between and across different scales to unpack the complexities of social and spatial transformations that are materially embedded and constituted in regions and their borders. Hence, the thesis adopts Paasi and Riding's conceptualisation of a region as a tool of analysis that allows the influence of different institutional and transformative regimes that influence QoL and the distribution of differing characteristics of NBS to be unpacked. Jones (2017) and Jones and Macleod (2004) argue that regions are multiple entities that can be territorial or symbolic shapes created through political representation through the drawing of borders and

boundaries, but they can also be spaces of economic exchange and trading, cultural identifiers and sources of belonging. Jones (2017) defines a region as a "*temporary permanence, something stable, not fixed and absolute, at different points in time for different purposes'* (pp. 1). Hence, Chapter 4 draws on Jones and MacLeod to explore the influence of divergent structural and historical inequalities that are prevalent across urban Europe and how these have influenced the distribution of the differing characteristics of NBS.

2.15.2 The City: a unit of analysis or constellation of concepts

The European Communities (2004) define a city based on territorial or administrative boundaries and population density. These spatial formations or boundary objects may consist of a city, wider city (or wider territorial unit or conurbation) and sub-city-levels. Hagan (2015) argue that this approach designates the city as a definitive and scientific object. This follows the Chicago School of Sociology tradition that follows 'city-as-a-representation' (Wachmuth, 2014) based on size and administrative units. It could be argued that the administrative units or Nomenclature (designation) of Territorial Units for Statistics (NUTS) (classification that are used by Eurostat to define cities represent the city-as-a-representation or boundary object. Castells (1983), Lefebrev (1991), and Harvey (1973) are highly critical of these notions of a city arguing that they represent the 'traditional' definition of the city based on 'class struggle' represented by dense agglomerations, economic centres, and society. In contrast, Hubbard (2017) argues the cities are complex and ever-changing but maybe "many things: a spatial location, a scale of analysis, a political entity or a mesh of social relations" (pp. 1). Thus, the city is a disputed concept that may be used interchangeably with urbanisation (Wachmuth, 2014).

Scott and Storper, (2015) and Wachsmuth (2012, 2014) suggest the city has evolved from being treated as an ecosystem (as an analogy to external systems) to an ideology of complex relational networks. This complex rational network has no rigid or absolute boundary but is underlaid by a common pool of resources and social conflicts, where nature is absent or external to the city. Similarly, Mumford describes these workings as a "theatre of social action" between the environment and people where cities' urban form and economic functions are secondary

(Legates, 2011). McFarlane (2011) also conceptualises the metabolic processes of the city as an assemblage created through uneven development, relations of history and future potential of capital accumulation, socio-cultural processes, and ecologies. Jacobs (2012) suggest cities increasingly also exist in an "era of increasingly geographically extended spatial flows" (Jacobs, 2012, pp. 412) where cities are open, discontinuous, relational, and internally whose geographies are not just networks of economic, cultural or political connectivity operating globally, but are also dissipated and emergent. These developments have led Wachmuth (2014) to claim that the city is no longer a category of analysis but a category of practice. Hence, while the secondary data published by the Urban Audit that the thesis draws on for analysis is based on administrative units that represent the city-as-a-representation, the thesis conceptualises the city as a mesh of socio-ecological and socio-political processes that interact with socio-economic and socio-cultural conditions where different conditions of environmental justice emerge, dissipate and reform through recurrent normative framings and hegemonic practices of politic elites deploying NBS.

2.16 Summary

Following a critique of the definition of NBS and key conceptual debates that relate to the framing, but also influence the enactment and implementation of these solutions, this chapter provides a theoretical framework that will be used to unpack the relationship between NBS and different economic and social conditions. Underpinned by this framework, an innovative methodology will be applied (Chapter 3) that will integrate different quantitative techniques to unravel the complex interactions that occur between NBS and different socio-economic and socio-political contexts at a macro-scale (Chapter 4). A heuristic approach is adopted in Chapter 5 to examine the influence of human-nature dichotomies on the distribution of different characteristics of NBS focusing on the nexus between governance-participation-citizen and how in turn this influences QoL or whether the conditions that NBS create lead to environmental justice. The relationship between the different characteristics of NBS and health at city-scale is explored in Chapter 6 drawing on inferential statistics and quantitative text mining approaches.

3 Methodology

This chapter elaborates on the data sources and sets out the epistemological and methodological framework used in the thesis. Firstly, sections 3.1 and 3.2 outline the research process undertaken by the Naturvation project and the methods used by researchers to collect data on the key characteristics of Nature-based solutions (NBS). Section 3.3 describe the secondary data sources that were used to represent different urban conditions in cities and the challenges associated with the use of secondary data sources. These indicators are selected to represent different concepts that relate to social vulnerability, socio-economic position, urban deprivation and poor health conceptualised in the literature review (Chapter 2).

Section 3.2 outlines the epistemological framework that forms the basis of the research design that evolves to reflect learning in the early stages of the research process from a post-positive stance to a meta-paradigm influenced by self-reflection and learning in the early stages of the research process. Section 3.2 discusses the influence of persistence of anti-quantitative narratives that became increasingly louder during my intellectual journey and a desire to challenge the boundaries that underpin the qualitative and quantitative divide by adopting a form of methodological pluralism (section 3.3). In section 3.3, the thesis outlines the initial influence of my work as a Demand Planning Project manager on positionality and ethical practice, and how this evolved, becoming critically reflective during the PhD journey. Finally, section 3.4 elaborates on the methods applied in Chapters 4, 5 and 6.

3.1 Urban Nature Atlas

3.1.1 Background Context

Chapter 2 outlined the critical conceptual debates surrounding the framing of the concept of Nature-based Solutions (NBS) and the role that scholars envisage they can play in a city's transition to sustainability and highlights the scarcity of evidence to support these claims. To address this gap, the NATURVATION project was tasked with pooling evidence from 1000 different projects retrospectively classified as NBS that were developed from the early 1990s to 2017. The project aimed to assess the different economic, social, and cultural contributions

these interventions make towards sustainability and how their different institutional, regulatory and financial arrangements influence innovation (Cooper et al., 2021; Naturvation, 2020). In collecting this data, the project aimed to improve our understanding of the challenges of implementing and maintaining NBS and provide an evidence base that can be used by actors considering deploying these interventions to support decision-making and business case development at a local level (Naturvation, 2020).

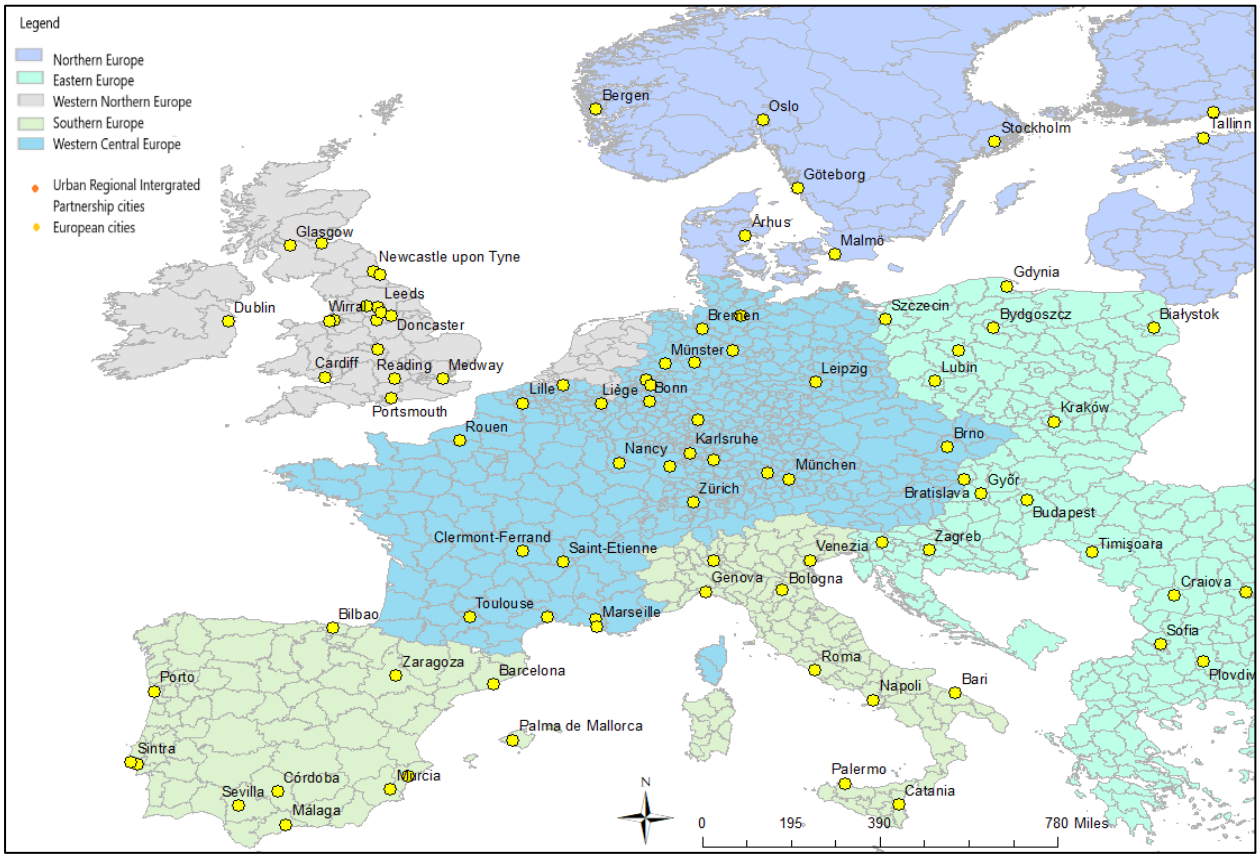

Figure 3-1 *Map of cities selected for analysis by the NATURVATION programme, including Urban Regional Innovation Partnerships (URIPs) (adapted from Almassy et al., 2017).*

3.2 Data Collection and Limitations

To collect evidence on a 1000 NBS, Naturvation chose 100 cities (Figure 3.1) to be included in the project, including 94 cities from the Urban Audit and 6 partner cities (Barcelona, Győr, Leipzig, Newcastle, Malmö, and Utrecht). Primary data for each case of NBS was facilitated

through the completion of a system-survey base through a web-based questionnaire platform, a data collection guide (Almassy et al., 2017) and training of data collectors from the Master's programmes of Central European University, Lund University and Utrecht University between spring and summer 2017. Hence, there was no opportunity to influence the research design, development of the training guide or quality control of the primary data as part of the study. Despite this, the data collection phase resulted in 997 questionnaires being submitted, of which 976 were processed for more detailed analysis by the Naturvation project team and subsequently used to create the Urban Nature Alas (referred to as the UNA hereafter).

Each web-based questionnaire was populated using secondary data sources such as project reports or other project documents, websites, news articles, blogs, etc. Then, the master's students interrogated the data using discourse analysis. These sources of data are often perceived to be plentiful and easy to access (Chua, 2022). However, Almassy et al., (2017) suggest data was often difficult to locate in some cities, and the time that each student had to complete a discourse analysis of each NBS was restricted to a week. Hence, the length of time students could spend searching for documents was limited or constrained by confidentiality issues (Almassy et al., 2017). Self-reflectivity is also of paramount importance in the studies to avoid misrepresenting narratives (Spilioti and Tagg, 2017). In contrast, Breeze (2011) and Chau (2022) argue objectivity is hard to achieve when using discourse analysis since the voice of authors is made invisible and the context is collapsed but suggest this is mainly due to a lack of ethics guidance on internet-based research. Hence, differences in language, availability of time, familiarity with discourse analysis may have influenced the methodological rigour, the extent of self-reflectivity and how consistently it was applied by each student, may have led to different interpretation of concepts (such as the type of ecological domain) across different NBS, influenced the depth of qualitative commentaries or accuracy of spatial data influencing the quality of the data published in the UNA.

3.3 Data variables from the atlas

Data collected including binary categorical variables that described the goals of the intervention, its key characteristics such as the ecological domain, scale, and primary

beneficiaries, but also the forms of governance, innovation and evaluation and learning being adopted by each NBS and qualitative commentaries for indicators such as the goals of the intervention or types of stakeholders involved in the governance of NBS (Almassy et al., 2017).

Naturvation used data collected by the researchers to create the UNA, an online open platform of over 1000 NBS from 100 European cities (Naturvation, 2017). Table 3-1 lists the data variables which form the basis of the data for this thesis. In addition to the data described in Table 3-1, master's students were also asked to collect spatial data that could be used to delineate and map the boundary of each NBS. In addition, textual commentaries accompanied some of the binary variables (to add context or further explanation regarding the variable in question) to aid understanding of the results (Chapter 6).

Urban Nature Atlas Data Variables	
General information	Grid reference co-ordinates to denote the spatial location of the intervention.
Objectives and Goals of the intervention.	Qualitative commentaries that briefly describe the intervention. This data is used to triangulate the statistical analysis presented in Chapters 5 and 6.
Key characteristics	
Ecological domains	Binary indicators that represent the number of different types of urban parks, community gardens or allotments, blue spaces, green areas for water management, derelict or vacant lots with wild spaces, external green buildings or indoor green areas. Each group of ecological domains are divided into different subtypes.
Ecosystem Services	Binary indicators that represent the number of each type of ecosystem service created by each NBS divided into provisional, regulatory, habitat supporting and cultural ecosystems services. Each group has a subset of services.

Governance	Binary indicators that represent the number of each type of governance used for NBS and different non-governmental actors leading governance.
Key Actors	Binary indicators that represent the number of each type of key actors and stakeholders involved in the planning and implementation of NBS
Participation	Binary indicators that represent the number of each form of participation adopted by actors deploying NBS. Range from co-planning to citizen management or implementation
Citizen Engagement	Binary indicators that represent the number of each form of citizen engagement adopted by actors deploying NBS. Range from participation in interviews or online forums to the collection of monitoring data for project.

Table 3-1 Summary of variables from the Urban Nature Atlas used in the study.

3.4 Urban Audit

The thesis also uses secondary data published in the Urban Audit, a dataset that consists of quality of life (QoL) indicators for cities published by Eurostat. The Urban Audit is one of the few QoL datasets available on a pan-European basis that includes: demographic, social, economic, environmental, training/education, and (for a limited number) health indicators for each city included in the city. Given the breadth of their coverage, these indicators can help illuminate how different urban conditions that influence QoL relate to the pattern of distribution of the key characteristics of NBS across Europe over time. Nolan and Whelan (2011) suggest data collected by Urban Audit plays a central role in capturing the everyday realities of poverty; poverty and deprivation can be associated with educational disadvantage, poor health, inadequate housing, and exclusion from the labour market. One of the main limitations of this dataset is that indicators that relate to trends in disease or subjective well-being are not available on a pan-European basis for cities. Hence, the analysis used mortality indicators published by the Urban Audit (Eurostat, 2017). Table 3-2 below summarises the indicators published by the Urban Audit that were used in the analysis.

Material	Social Conditions	Social Vulnerability Groups	Health Outcome Indicators
Education attainment	Households in social housing	Lone pensioners	All-cause mortality
Average or median income	Households in private housing	Households with dependents	Mortality due to heart or respiratory disease
Poverty due to social transfers	Owner-occupier households	Lone parents with dependents	Infant Mortality
Poverty due to low working hours	Dwellings that lack basic amenities	Foreign citizens born in EU country and non-EU country	All-cause mortality related to gender in citizens under 65 years
SILC Occupation indicators	The average size of living space		

Table 3-2 quality of life indicators published by the Urban Audit adopted in this study (Eurostat, 2017)

A second challenge with the use of secondary data published by the Urban Audit was the granularity of available data. Data for each indicator was published based on three spatial units: Functional Urban Area (FUA), Greater City and City. However, early exploration of the Urban Audit indicators revealed that data availability for each indicator (summarised in Table 3-22) varied by spatial unit, reference year, and city. Data published in the Urban Audit is provided to Eurostat voluntarily based on census or survey data collected by member states. However, in some states, data is not collected or may be modelled or estimated, reducing their reliability (European Commission, 2004). Hence differences in the approach to defining spatial

boundaries of the city, FUA and Greater City and data quality issues were a key limitation of this thesis, making the comparison of QoL between cities more challenging.

These scholars highlight that gendered-disaggregated data is often not only underrepresented or non-existent as a variable when assessing the gender-related impacts of climate change in medical and environmental research. Springer et al., (2012) and Krieger (2003) argue that sex-linked biology and gender-based differences are deeply entangled epidemiological and health research. Krieger (2003) highlight that sex and gender are often used interchangeably but are distinct constructs: gender is a social construct while sex-linked biology is a biological construct. Springer et al. (2012) argue the influence of gender can not rely on the dichotomisation of sex-linked biological categories, males, and females, but do include gender effects. While Springer argues that sex-linked biology should not be used as a proxy for gender, Krieger (2003) suggests that sex-based and gender-based measures may be independent or synergistic determinants depending on the specific population of study.

3.5 Scene setting: Ontological Framework

3.5.1 Post Positivist Ontology

Positivism is a set of philosophical approaches thought to originate from the work of Auguste Comte (1978-1857), claimed to underpin philosophical foundations of the quantitative revolution and spatial science (Creswell, 2013; Kwan and Schwanen, 2009). Positivism assumes that truth can be revealed through measurement or instrumentation and empirical analysis based on extensive use of quantitative techniques theory of causality (Wyly, 2014; Adam 2013). Methodologically, the thesis begins situated within a post-positive ontology, integrating different quantitative methods to explore the distribution pattern of each of the variables presented in the UNA and Urban Audit.

Critiques of positivism (Steinmetz 2005; Clarke, 1998) suggested that scholars attempt to use philosophy to justify methodological reductionism describing it as methodological positivism. These critiques are reflected in Marshall (2006) and Cloke and Johnston (2005) account of attempts to make geography 'more scientific' in its quest for independence, drive for political

respectability and advance methodologically in the 1950s leading to the quantitative revolution (Cloke, 1991). Positivism later lost favour as scholars (see Cloke and Johnston, 2005; Smith, 1979; Lake, 1993) criticised the exclusion of values and meanings that underpin observed phenomena leading to the dismissal of processes of production and reproduction (Kwan 2009; Graham and Shelton 2013).

According to Smith (1979), Lake (1993), Johnson et al., (2019) and Harvey (1969) the rigorous dichotomy between fact, values, theory and practice not only leads to 'othering' due to its failure in its encounter with ethics but also deductive methods of computation lead to misrepresentation (Kwan 2009; Graham and Shelton, 2013) and reduce observed relationships to a fixed definition (Sheppard, 2001; Lake 1993). Within geography, critiques argue that quantitative geography influenced by logical positivism primarily operated in a philosophical vacuum that imposed self-limiting analytical constraints that removed subjectivity. Other scholars argued that a positive ontology limit understanding of the world to single truths, blinding our understanding of these complex phenomena and obfuscating positionality by limiting the scope for reflexivity (Kwan and Schwanen, 2009; Kwan, 2009; Sheppard, 2001). Furthermore (Crampton and Krygier, 2018; Kent and Vujakovic, 2017; Crampton, 2010; Lake, 1993) also argue the separation of the subjective and the objective is not only inherently power-ladened but can also be used as a political instrument that privileges and reinforces existing dominant political structures. In contrast, Merry (2016), Berman and Hirchman (2018) and Bourdieu (1984) challenged the notion that quantified data is truly 'objective'. These scholars argue that subjective data are not free of value judgements and perceptions made by those agents that classify them.

3.5.2 The influence of anti-quantitative narratives and post-positive ontology

While acknowledging the limitations of positivism, other scholars (see Sheppard 2001; Kwan, 2004; Johnston et al., 2014) argue these critiques reflect persistent anti-quantitative narratives that connect epistemology and methodology, leading to the emergence of qualitative-quantitative dualism. Despite efforts to respond to these critiques and bridge this divide (see review by Sui and Delyser, 2012), Johnson (2014) argued the ‘taken-for-granted bracketing’

of quantitative geography and positivism persists, devalues empirically, evidence-based social science. In response to these critiques, a branch of post-positivism emerged that aimed to update, but not replace positivist ontology by offering a more complex or hybrid research design (Kwan, 2004; Schwanen and Kwan, 2007) that integrates different combinations of methods or adopts triangulation in a form of methodological positivism (Wyly, 2009). Through mixed methods, these hybrid geographies aim to bridge methodological divides. However, Sui and Dysler (2012) and Elwood (2010) argue that epistemological and philosophical divides must be addressed if the discipline is to bridge persistent divides and anti-quantitative narratives. Hence, in the first empirical chapter, the thesis attends these debates by adopting a post-positive ontology that integrates different quantitative methods (Chapter 4) to unpack the influence of power structures on the distribution of the differing characteristics of NBS both at socio-economic level and macro-region.

3.6 Methodological Pluralism bridges the quantitative-qualitative divide

Scholars argue (Creswell and Clark; 2017; Elwood, 2010; Tashakkori and Teddle, 2003) that adopting methodological pluralism or a hybrid research design can enhance the exploratory power of research by allowing for a more reflective approach (Panhwar et al., 2017). Furthermore, Johnston et al., (2020) argue "science is a communal affair with multiple inroads to the destination of truth" (p5). According to Panhwar et al., (2017), Elwood (2011) and Clark (2008) a hybrid research design can reveal insights into different patterns structural relationships that go beyond the analysis of quantitative or qualitative data alone and displace the dichotomy between the qualitative-quantitative divide by forging connections and challenging boundaries within complex geographies. Hence, in the subsequent empirical chapters, the paradigms that influence my research design evolve by self-reflection on learning during the first phase of research (Bourdieu and Waquant, 1992). Chapter 5 is influenced by an interpretative view (non-positivist creative realist) enabling the 'mechanisms' or historical or institutional that influence different patterns within the UNA and Urban Audit data to emerge. Chapter 6 is underpinned by pragmatist ontology (Hesse-Biber, 2012; Fielding, 2012). Hence, in transitioning across these paradigms or meta-paradigm, the thesis adopts a dialectic stance so as not to privilege one paradigm above others (Green and Caracelli, 1997). Like

Tashakkori and Teddle (2010, 2011), Chapters 5 and 6 embark on a form of methodological 'eclecticism' to unpack the complex relationship between different characteristics of NBS and social and economic conditions that influence urban deprivation, social vulnerability, and poor health in cities.

Bourdieu (1979) and Bourdieu and Waquant (1992) argue that it is possible to develop an integrated, structured approach to social enquiry based on the premise that both material and social phenomena are highly intertwined weaved together in a relational 'social praxeology' (p.11). Thus, in Chapter 5, quantitative relational methods (Bourdieu, 1984; Grenfell and Lebaron, 2014) such as Geometric Data Analysis are drawn on to analyse structural relationships that emerge between different framings of NBS that have evolved, the influence on the governance- participation-citizen involvement nexus, and the relationship of these patterns with different social and economic factors in cities.

In Chapter 6, inferential statistics and Cramer's V size effect are used to examine the relationship between different types of NBS, the ecosystem services they provide, and the effect size on adverse outcomes and triangulate these results using quantitative text analysis. In adopting this approach, 'two cultures' of knowledge production are mixed (Ignatow and Mihalcea, 2017), thereby rejecting the incompatibility thesis. In doing so, the thesis aims to "transgress and displace boundaries between binary divisions" (Rose, 2000, p.364) by mixing elements thought to be incompatible or conflicting (Sui and DeLyser, 2012, 2013). While scholars argue that these cultures, scientific and humanistic, are premised on entirely separate epistemological and ontological positions that are incommensurable (Ignatow and Mihalcea, 2017), several scholars (Hesse-Biber, 2012; Fielding, 2012; Oleinik, 2011) suggest a multi-method or 'between method' (i.e. two distinct methods to analyse the data) approach to triangulation can aid understanding of complex relationships. Hence, in the final empirical chapter, the statistical analysis of the relationship between different characteristics of NBS and health and quantitative analysis of textual commentaries published in the UNA using Multidimensional Scaling and Co-occurrence Network Analysis are done in parallel to begin to explore the interrelationship between NBS and health (Chapter 6).

3.7 Positionality and Research Ethics

3.7.1 Positionality

Prior to embarking on this intellectual journey, day-to-day work as a Water Demand Project Manager was largely situated in a post-positive paradigm where scientific rigour and analytical reasoning (Creswell, 2013; Kitchen, 2015) were important to ensure statistics were reported to Government and regulators were accurate and auditable. However, as the intellectual journey evolved so did the relationship between myself and the data; evolving from that of an outsider to an insider (Rose, 1997; Harraway, 1991; Ricker, 2017) becoming increasingly reflective tensions between the data quality and issues of representation emerged (see section 3.2 on Ethical Considerations). An evaluation of the spatial data published in the UNA suggested that master's researchers were unable to collect sufficient spatial data from delimiting the spatial boundary of each NBS correctly. Consequently, the collection of spatial data was limited to the collection of single-point data and in some cases, researchers did not collect any spatial data, but used the centre point of each city as the geolocation of each NBS. This distorted the absolute location of the features of the NBS.

To navigate these tensions, the research drew on the scholarship of Espeland and Yung (2019) and Merry (2016) who argue that it is essential to look behind the source data to evaluate the concepts and assumptions that underpin datasets and their uneven development. Evidence suggested that lack of available time to pinpoint the location of the NBS on a map, the positionality or the methodological preference (qualitative versus quantitative methods) of the Master's researchers may have led to some types of knowledge being privileged above others leading to some forms of knowledge being excluded from the data collection process. While data are not perfect (Wolf et al., 2021) it could be argued that methodological preferences, misunderstandings about what quantitative geography or spatial analysis actually is, or anti-quantitative narratives may have led the collection of qualitative data being prioritised over spatial data. Hence, a lack of knowledge and understanding of quantitative geographies may have, inadvertently, reinforced existing dichotomies between qualitative and quantitative data that have fuelled the quantitative-qualitative divided (Johnston et al., 2014). Consequently, the spatial data collected by the Naturvation project may have become power ladened. Similarly,

to Kwan and Crampton et al., (see section 2.1), Chun et al., (2019) and Griffiths et al., (2015) highlight that uncertainty in spatial data affects the truthfulness of representations of spatial patterns in data and results in substantial errors in spatial analysis. Hence, while scholars (Kwan, 2016; Safransky, 2020) argue quantitative geographies commit violence on data ontologies, it could also be argued that unequal treatment of quantitative and qualitative data collection during the data collection process is also a form of ontological violence. Consequently, issues of power and misrepresentation often critiqued by critical geographers (see Crampton 2010; Kwan, 2004, 2009) had a significant effect on the research design for the study. Erroneous point source grid references for each NBS cleaned and those NBS without accurate data were removed from the sample. To address the issue of lack of or erroneous data, maps and photographs that showed the extent of the spatial boundary of each NBS could have been digitised, but there was insufficient research time to apply this method affecting the approach and research design adopted in the thesis.

3.8 Ethical considerations

The research was subject to the ESRC's code of ethics and an ethical review following Durham Universities' policy on Ethics in Research. Data from the UNA were subject to an ethics review for the Naturvation project, and Urban Audit is open-source secondary data. Thus, an initial ethics review identified no significant issues influenced by my role as an 'outsider' in my previous job. One of the responsibilities of this role was to analyse water demand trends, primarily using quantitative indicators in an industry that rarely challenges the origins of normative assumptions that underpin data collection. However, as the research progressed ontological and ethical tensions began to emerge when probing the Urban Audit data due to missing data and methodological limitations. Cunningham (2020) and Rottenberg and Merry (2015) argue that data are never objective or neutral. These scholars argue those analysing data should reflect on the epistemologies that underpin the data collection process and analytical interpretative decisions made (Ricker, 2017; Thatcher, 2014), and the role of governance and finance on these processes (Rottenberg et al., 2015; Merry, 2016). These limitations became apparent as the relationship with the data evolved and led to an increasing uneasiness about creating numerical representations using data that had counting errors or missing data and the

lack of transparency behind theoretical assumptions that underpinned the data (European Union, 2017). An evaluation of the metadata for each Member state also showed that some states had not updated national censuses since 2011. Furthermore, monitoring and collecting some of the Urban Audit indicators had not begun when some NBS was implemented combined with methodological changes to the Urban Audit in 2013/14 reduced the number of indicators being collected, reducing the availability of data for analysis.

Espeland and Yung (2019) and Merry (2016) argue that three issues mediate the ethics of quantification:

- The role of power in decision making about which data to collect and selection of neat categories of analysis.
- Merry argues that objectification reduces social groups, people, or aspects of social life invisible through translating complex social and cultural phenomena into neat categories of analysis.
- It results in the misrepresentation of phenomena by removing context and history.

Section 3.3 briefly outlines the tensions that were encountered as my relationship between the data evolved from an outsider to an insider (Rose, 1997; Harraway, 1991; Ricker, 2017). To address these tensions, the research drew on literature on the ethics of quantification (see Saltelli et al., 2020a, 2020b; Merry, 2016; Berman and Hirschman, 2018; Depelteau 2013; West et al., 2020). Merry (2016) and Berman and Hirschman (2018) suggest the sociology of quantification literature offers a framework or compass for data-activism in which the researcher or the 'quantified self'. Merry (2016) recommends tracing histories within the data to pay attention to what Merry refers to as "expertise inertia" (or who counts as an expert) and who makes decisions about what data is collected. Merry also encourages reflection on questions about what is "data inertia" (or what kinds of data are relevant) by examining metadata or data flumes (Ricker, 2017).

3.9 Methods

This section of the chapter outlines each of the methods that were used in the thesis. Figure 3.2 charts the relationship between each empirical chapter and each method discussed in the sections that follow.

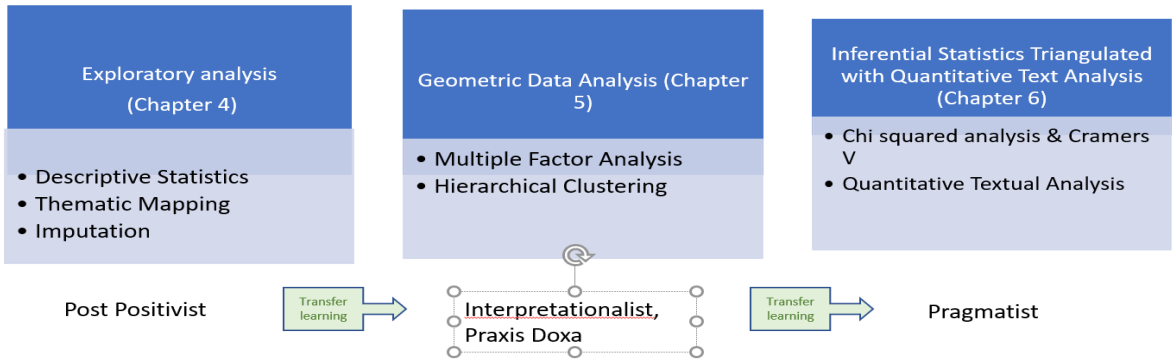

Figure 3-2 Relationship between ontology and methods underpinning each empirical chapter

3.9.1 Exploratory Data Analysis

Following autonomous counting (Hannah, 2011), researchers from the Naturvation project transformed qualitative data from the questionnaires into binary categorical variables representative of urban conditions of NBS. Whilst noting the limitations of the UNA dataset based on the critique of Kwan (2009), Graham and Shelton (2013), exploratory data analysis (EDA) is an operative approach and a fundamental step following the collecting and processing of data (Vigni et al., 2013; Komorowski et al., 2016) that focuses on the exploration of the data to reveal patterns and trends that are unknown. According to Leek and Peng (2015) and Komorowski et al., (2016), EDA enables the researcher to discover patterns within the data and detect outliers to gain insight into the data to make discoveries and generate hypotheses, but it cannot be used to confirm or establish causality in those relationships. Despite this limitation, Ghosh et al., (2018) and Rogerson (2015) argue that EDA enables researchers to begin to unpack patterns in data, especially in large datasets that are highly dimensional in a structure such as the UNA and Urban Audit. Hence, to begin exploring the characteristics of NBS and how these relate to objective indicators of QoL descriptive statistics, box plots and histograms

were used to identify trends, missing data and outliers in the Urban Audit dataset (Shreffler and Huecker, 2021; Ghosh et al., 2018; Chatfield, 1986).

3.9.2 Pattern of Missing Data and Imputation

Navigating and tracing the histories of the Urban Audit data was a messy and entangled process that involved following hyperlinks inside numerous spreadsheets and methodological documents to unpick ambiguous explanations of methodological assumptions or changes and probed explanations for missing numbers. Feedback was given to the research team responsible for the data collection within the Naturvation project to address inaccuracies in spatial data. In the case of the Urban Audit dataset, several variables had more than 5% of cases with missing data. Unfortunately, there were no other sources of open data available on a pan-European basis for cities. Despite concerns about the representativeness of the data, a decision was made to analyse the pattern of missingness in the data and impute the missing variables, which is recommended for variables that include more than 5% of missing cases (Rubin, 1987; Schafer, 1997).

Initial exploratory analysis of the Urban Audit data showed that some cities were missing variables for the reference year of interest. A review of the literature suggests that there are several different methods for handling missing values in datasets that include: complete case analysis, mean infilling or single imputation (Van Buuren, 2018; Zhang, 2016), but these are associated with bias due to over or underestimation of parameters (and standard errors). In contrast, multiple imputation, first proposed by Rubin (1987), uses a prediction model to estimate missing parameters; after several iterations, results for each dataset are pooled and used to estimate the parameter of interest, avoiding overestimation (Van Buuren, 2018; Zhang, 2016). However, Van Buuren (2018) also suggests that multiple imputations is not without its problems since differences in types of variables, collinearity, the order of rows and columns, and the complex relationship between observed and predicted variables can affect the quality of the results. Morris et al., (2014) suggest two approaches to modelling that may be adapted based on the type of data: predicted mean matching for continuous variables or logistic regression for categorical or binary variables. Hence, the thesis adopts multiple imputation

using predictive mean matching a semi-parametric approach to fill-in incomplete observations accounting for the probability distribution of the missingness of the observations when modelling the fill-in values (Horton and Lipsitz, 2001).

The thesis utilises MICE package in R Software to impute the Urban Audit indicators; MICE uses a modular approach (shown in Figure 3.3) to multiple imputation (Van Buuren and Groothuis-Oudshoorn, 2011) that begins an analysis of the pattern of missingness that is associated with each variable using the margin plot function (Van Buuren, 2018). Seminal work by Rubin (1976) suggests that there are three patterns of missingness: missingness completely at random (MCAR), Missing at Random (MAR) or Not Missing at Random (MAR). In MCAR, the reason for the pattern of missingness is completely random, while in MAR, the pattern of missingness is also independent. However, the pattern is traceable or can be predicted from other variables. In contrast, the pattern of missingness in NMAR is not random but relates to missing variables (Garcia-Laencina et al., 2010), This allows the researcher to compare the pattern of complete and missing observations and determine the pattern of missingness.

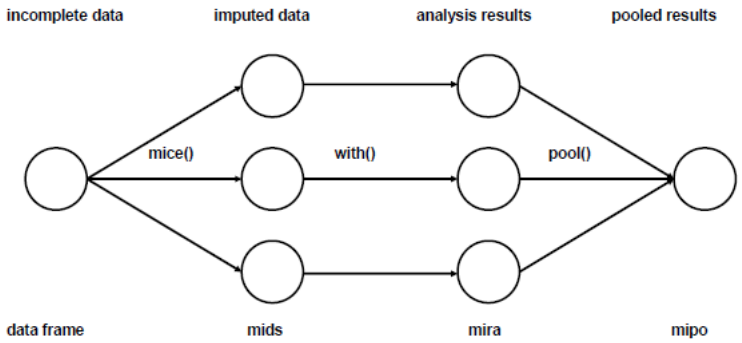

Figure 3-3 Stages of Multiple Imputation in Mice (source: Van Buuren and Groothuis-Oudshoorn, 2011)

On confirming the pattern of missingness and appropriateness of the imputation method, the MICE package iteratively generates successive chains of algorithmically generated values in a process referred to as Markov Chain Monte Carlo (MCMC) based on the probability of missingness of the parameter (Gill, 2007; Van Buuren and Groothuis-Oudshoorn, 2011; White

et al., 2011). This process creates successive imputations (specified by the researcher) of the missing parameter based on the probability of occurrence of the predicted value. The distribution of the observed and predicted variables generated by each iteration are compared using the strip plot function (Figure 3.4). In this case, ten iterations were complete based on Bodner et al., (2008) for each variable. The new datasets were converged using the Pool function in MICE, considering the variance across each dataset (Van Buuren and Groothuis-Oudshoorn, 2011, 2015).

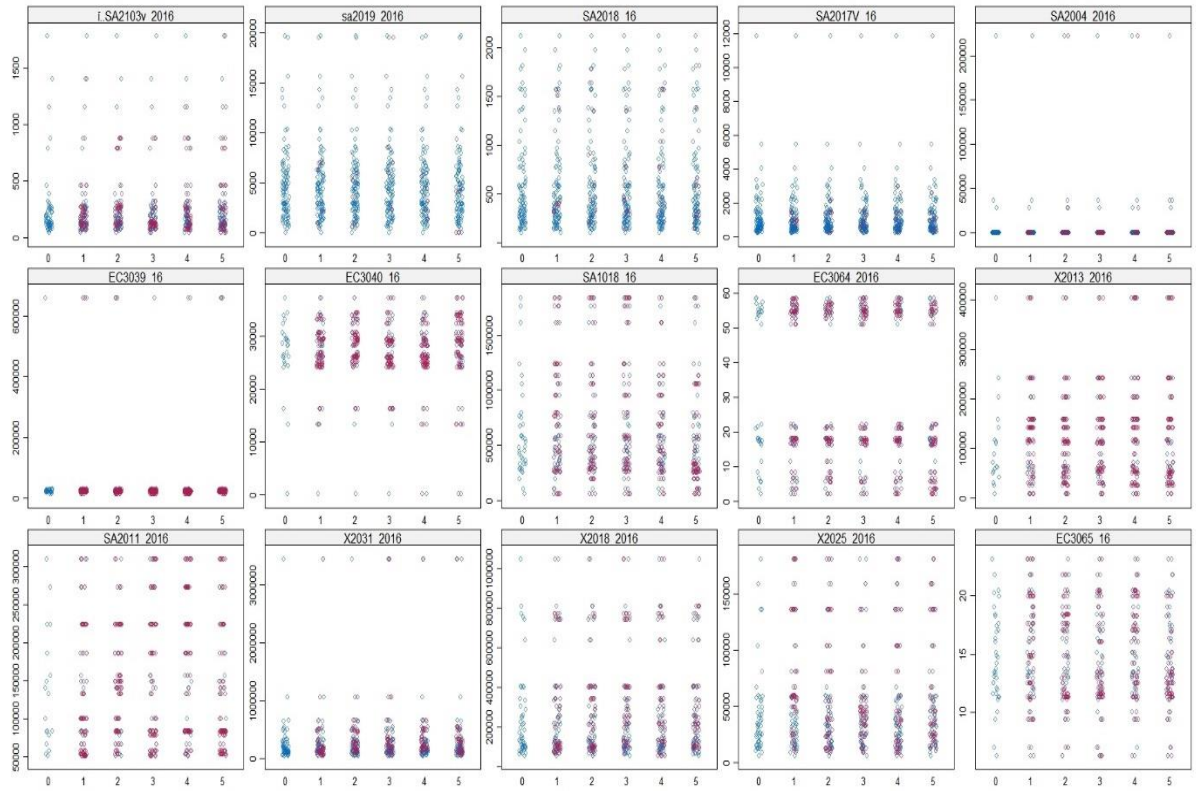

Figure 3-4 Strip plot of observed and predicted values of Urban Audit dataset (the reference year 2016)

3.10 Thematic Mapping

To help visualise the spatial distribution of the data identify gaps in data and interrelationships between different phenomena across and between cities, Member States and European Regions, thematic maps were created in ArcGIS using spatial boundary datasets published by

Eurostat. Whilst paying noting the critiques of Crampton et al., each city of the 100 cities that feature in the UNA, was classified into one of five European sub-regions: Eastern, Northern, Southern, Western (Central) or Western (North) Europe. This follows an approach developed by Eikemo et al., (2008), who classified Europe into three Western European sub-regions and Eastern Europe (based on historical and political factors) to compare health inequalities across Europe. Each variable was aggregated to calculate the total number of characteristics in each sub-region. Due to sampling limitations, the distribution of cities across Northern, Western, Southern and Eastern Europe is uneven. Thus, the results were normalised using the factors summarised in Table 3-3 based on the approach developed by NIST (2017).

European sub-region	Number of NBS	Weighing Factor
Eastern	189	0.97
Northern	72	0.37
Southern	215	1.10
Western (Central)	268	1.37
Western (North)	232	1.19
Average	195.2	

Table 3-3Weighting factors applied to each European sub-region to normalise the distribution of NBS

Scholars (Juergens, 2020; Sknowronnek et al., 2015; Kelly, 2017) suggest choropleth maps are one of the most commonly used methods and a powerful strategy to visualise area-based information and highlight geographical differences in the spatial distribution of data. The technique has been widely used to illustrate trends and enhance insights by using different shadings, colours and patterns and classifying data to limit the number of classes (MacEachren, 1995; Brewer and Pickles, 2002; Kraak and Ormeling, 2020). Although Tobler (1973: Kraak and Ormeling, 2020; Juergens, 2020; Sknowronnek et al., 2015) argued that it was not necessary to classify data since it can dramatically alter the result (Monmonier, 1972; Brewer and Pickle, 2002). This thesis will not elaborate on the debates surrounding the classification schemes but will adopt the method developed by Jenks (1963). Thus, a series of choropleth maps were created using the NUTS (Nomenclature of Territorial Units for Statistics)

classification and spatial boundaries of Urban Audit developed by the European Union. Spatial boundary data as the basis of the map layout. To create socio-economic or macro-regional boundaries, NUTS 1 boundary data representing each member state's boundary was merged in ArcGIS based on the classification developed by Eikemo et al., (2008).

3.11 Geometric Data Analysis

Geometric Data Analysis techniques including PCA, MCA, multidimensional scaling, and MFA were applied to create a Euclidean cloud representing clouds of data points in multidimensional space. Bourdieu (1984) deployed MCA, a Geometric Data Analysis technique that allows the complex relationships between social practices (Habitus) and complex interactions between categorical indicators to be investigated. Similarly, Le Roux et al., (2019) and Lebaron et al., (2018) argue that systematic analysis of patterns in complex, multidimensional datasets require the use of GDA techniques that take a heuristic approach to analyse the structure of complexity in order to dig out what the data has to say. To carry out this analysis, I utilised an open-source platform, R software, drawing on the FactoMineR to complete GDA to unpack the structural relationships within the UNA and Urban Audit. Miller and Goodchild (2015) argue that these methods are data-driven since they are selected to satisfy the data rather than the data configuring the method. However, these methods also allow scholars to explore the global characteristics of the data to inform further research or analysis provided that critical reflexivity is practiced evaluating the role that different algorithms and their interactions with the data might influence the results (Kwan, 2016). Considering the challenges that were encountered with the data, critical reflectivity was paramount throughout the research process. Hence, different GDA techniques were applied using different packages in R software to ensure that the most appropriate method was selected. Lebaron (2021) argue that GDA techniques allow the researcher to operationalise a systematic and relational appraisal of their research at each stage of the process. This reflectivity can be illustrated by an example of Multiple Correspondence Analysis (MCA) (Bordieux, 1984; Lebaron and Bonnet, 2014) that was carried out to analyse trends on a subset of categorical variables held by the UNA in an early stage of the research.

MCA is an extension of correspondence Analysis and a generalisation of PCA that analyses the pattern of relationships of categorical data such as indicators published by the UNA (Greenacre, 2007). An initial review of the results (Figure 3.5) suggested nine clusters of NBS. However, comparison with the scree plot showed the first principal component represented less than 5% of the variance due to the binary nature of the dataset (i.e. most variables are 0 or 1). Hair et al., (2012) recommend that at least 60% of the inertia should be found in the first five dimensions of the analysis. To adjust for low levels of inertia in each dimension, Benzecrzi (1979) and Greenacre (2007) recommend the application of a correction formula. However, the results showed that the quality of representation of each principal component did not improve; hence, Multiple Factor Analysis (MFA) was undertaken. This method computes a global PCA followed by MCA to balance the distribution of inertia across each group variable at each node in the hierarchy, ensuring correct representation of the characteristics of the UNA (Le Dien and Page, 2003; Escofier and Pages 1990; Pages and Husson 2014; Le Roux et al., 2019; Lebaron and Bonnet, 2014).

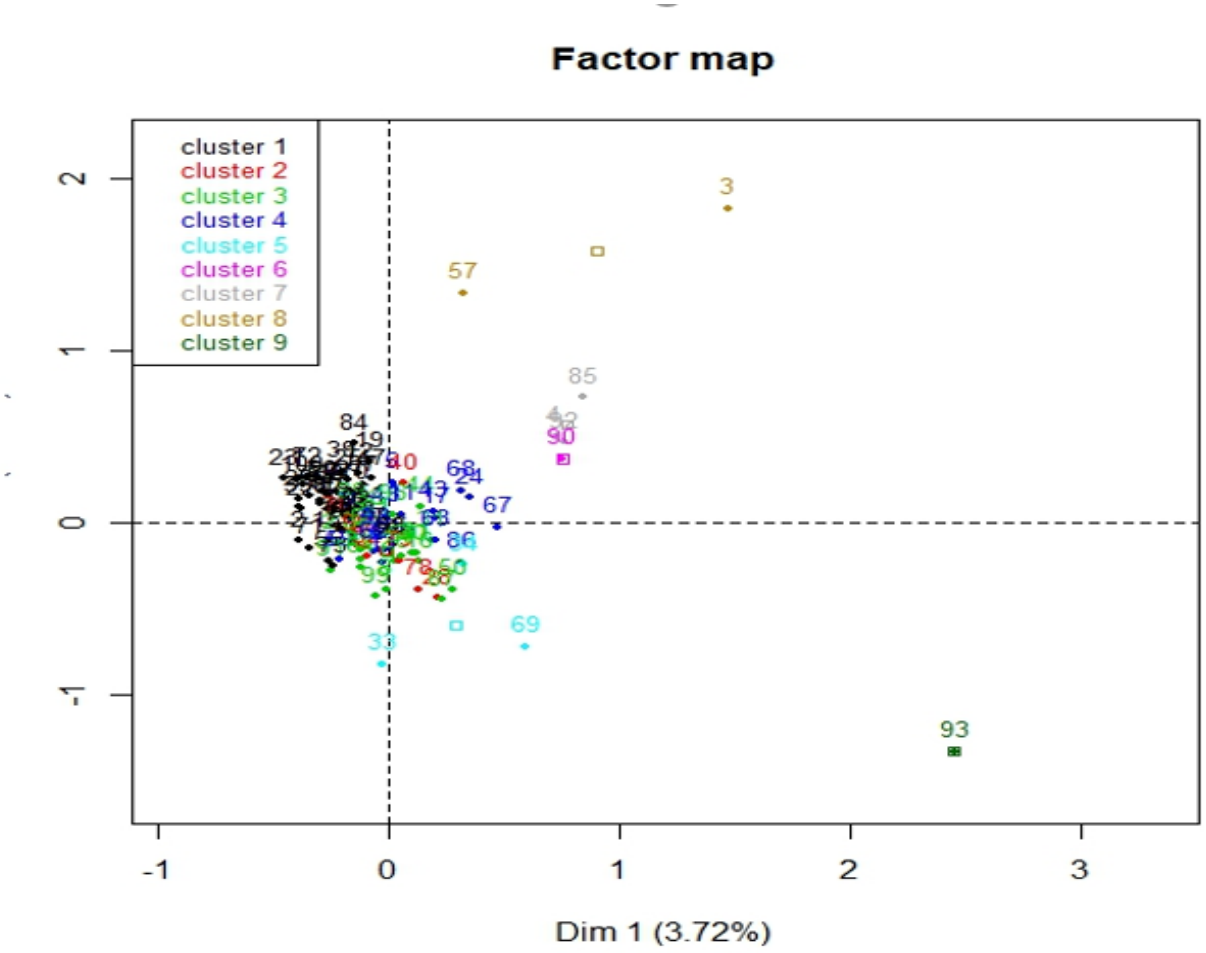

Figure 3-5 *Initial factor map created using MCA followed by hierarchical clustering*

3.11.1 Multiple Factor Analysis

Multiple Factor Analysis (MFA) is an extension of PCA developed by Escoffier and Pages (1990, 1994) that brings together elements of PCA and MCA to analyse multiple data tables assembled in a multi-block dataset (Abdi et al., 2013). Like PCA, MFA is a geometric data analysis (GDA) technique that represents structured datasets as clouds of points in a multidimensional space (Le Roux et al., 2019; Lebaron and Bonnet, 2014). Unlike other similar techniques such as PCA, MFA simultaneously analyses the strength of the relationships between different observations described by multiple blocks or sets of variables defined by the same set of observations within a structured data matrix as well as individual variables (Ecofier and Pages, 1994).

Thus, MFA is selected to analyse the network of relations between the different characteristics of NBS, both their group (e.g. type of ecological domain or modes of governance) and sub-categories (e.g. large urban park, pocket parks, etc) and different indicators that represent social conditions, deprivation, vulnerability and health are related in three-dimensional space and their role in influencing alleviating or reproducing conditions that lead to poor health and environmental justice. To achieve this, two multiblock datasets or matrix consisting of 30 groups of variables from the UNA and Urban Audit are categorised based on the structure type of indicator. Groups of variables from the UNA consist of a taxonomy of ecological domains, ecosystem services, scale and primary beneficiaries, but also the forms of governance, participation innovation and evaluation and learning. Data from the UA and socio-economic adversity indices were separated into four groups: social, deprivation, vulnerability, and health. These indicators are normalised using z-scores to create a typical representation of the dataset.

Using the FactomineR package in R software, we compute a Multi-Factor Analysis (MFA) to 'follow the thing' (Sui and Delyser, 2013) to trace the network of relations between different characteristics of NBS and the differing structural conditions in three-dimensional space and visualise the results in the FactoExtra package (Le, Josse and Hudson, 2008; R Core Team, 2000). Initially, a PCA is completed to decompose the variance into a set of orthogonal variables or principal components (referred to as factors in the thesis) whose ordering is based on the amount of variance explained by each principal component. Scree plots (Figure 3.6) that summarised the principal components from this phase of analysis were reviewed. The loadings for each variable were compared to the frequency counts for each indicator to ensure the loadings represented raw data. MFA then conducts a canonical correlation analysis (Pages, 2015) to differentiate between structural relationships between groups of variables and their subsets based on the similarities/differences in the attributes of these groups allowing the complex pattern of networked relationships between different characteristics of NBS, social and economic conditions and the influence on environmental justice to emerge. The contribution of each indicator to the factor loadings of each principal component or factor was compared to findings from the exploratory analysis (Chapter 3) to check the representation of

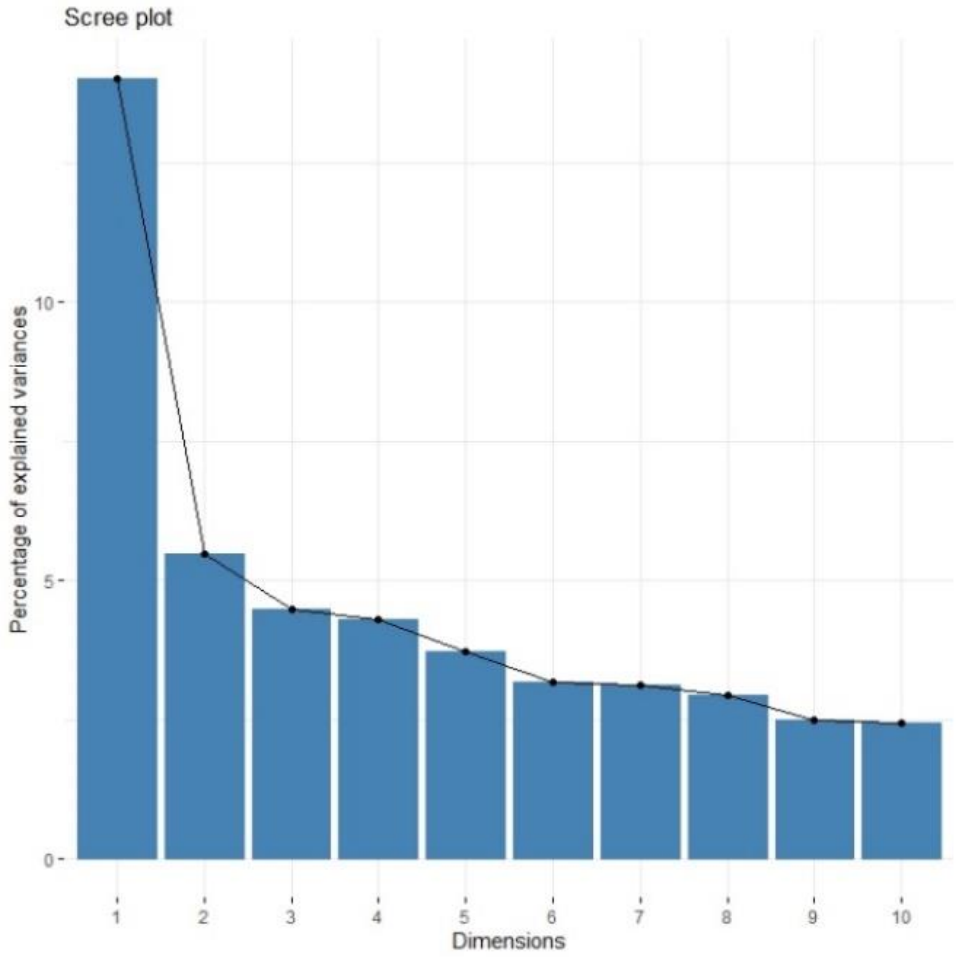

Figure 3-6 Example scree plot showing the percentage distribution of variance explained by each principal component

the data. Lebaron (2021) argues that the researcher can "locate oneself by use of the projection of the 'external' clouds of individuals followed by particular analysis of any potential biases orblindness" (p131). Locating oneself within the projection of factor loadings of each principal component revealed the multi-layered structure of interrelations between different characteristics of NBS such as modes of governance, participation, and implications for environmental justice. This allowed patterns or consolations of characteristics that interact with structural conditions to influence health outcomes negatively or positively to be identified. This approach to reflexivity was repeated for each multiblock dataset (NBS implemented before 2009 and those implemented after 2010) to explore how these patterns of different types of

ecological domains, governance, modes of participation evolve temporally as the deployment of NBS gathers pace across urban Europe begin to understand their influence on social and health inequality in cities.

3.11.2 Hierarchical Clustering on MFA

To further explore if there was any evidence of nested relationships between different combinations of characteristics of NBS and structural conditions common to all cities, only some cities or just specific cities the first five factors from the MFA analysis were selected for Cluster analysis. Cluster analysis is a method of unsupervised machine learning used to identify groupings or partitions data based on measures of proximity between pairs of objects (or data variables) (Gulagiz and Sahin, 2017; Hennig et al., 2015; Caruso et al., 2017; Balijepally et al., 2011). Widely used in biology, psychology, and economics (Kodinariya and Makwana, 2013), cluster analysis identifies groupings within a dissimilarity matrix based on partitions within the data that are 'hard' or categorical or 'soft' based on the degree of membership within each group or cluster. There are many different methods of clustering (for an extensive review of methods, see Xu and Tian, 2015), but the most common include hierarchical and non-hierarchical methods (Hennig et al., 2015). Hierarchical methods involve a series of decisions in which data objects are brought together in a hierarchy or tree-like structure. There are two different classes: agglomerative or bottom to top when groups are merged and divisive or top to down approach where the partition of the clusters are split through a series of successive iterations based on the distance between data objects (Everitt et al., 2011).

In contrast, non-hierarchical approaches do involve a tree-like construction process, but instead, data objects are assigned to clusters once the analyst has specified the number of clusters. To start the process, cluster seeds may be assigned, or the algorithm may randomly select the seeds for training. Then each data object is successively paired with a cluster based on the distance of the object and the centre of the cluster using K-means, K-Medoids or Partitioning Around medoids (PAM). It is not the aim of the thesis to further elaborate on these here, but these approaches are more efficient in terms of calculation time since once the analyst

determines the number of clusters prior to analysis (Everitt et al.,2011; Inekwe et al., 2020; Shi et al., 2021; Gulagiz and Sahin, 2017).

In contrast, Hierarchical Clustering is more heuristic as the researcher or data analyst defines the groups by cutting the dendrogram at an appropriate level by the data analysts. Defining the partitions is an iterative process that provides an opportunity for the membership of each cluster to be reviewed to ensure that it is representative of the data. Thus, hierarchical clustering is performed using the HCPC function in the FactomineR package to measure inter-and intra-class variability of the data objects and their pattern of clustering across cities based on Ward's (1963) criterion that looks for clusters in multidimensional space (Husson et al., 2010). Selection of the optimum number of clusters for analysis was based on the calculation of the GAP-statistic (Tibshirani et al., 2001; Hastie et al., 2009) which compares the error rate with the value of K. Figure 3.7 compares the optimum number of clusters based on calculation of the GAP method and the Elbow method using the Factoextra and NbClust packages in R software. However, there is less opportunity for reflectivity with non-hierarchical clustering because once the number of clusters has been assigned, the algorithm will find the optimum solution.

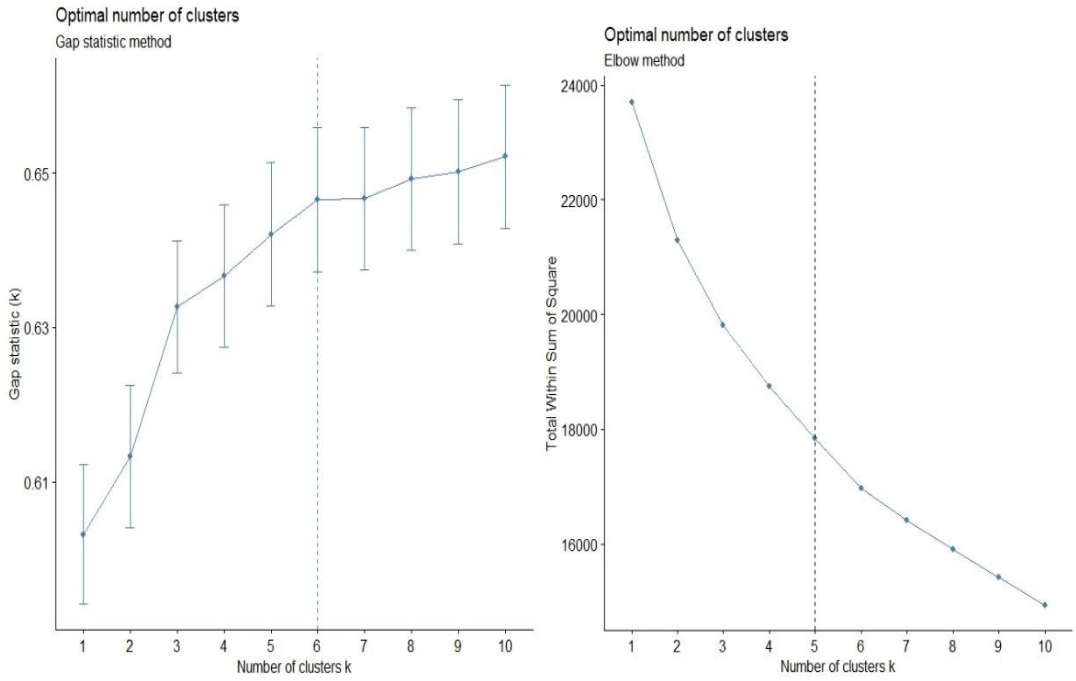

Figure 3-7 Optimum number of clusters based on GAP-statistics and Elbow Method

3.11.3 Inferential statistics

In the final empirical chapter (Chapter 6), the thesis adopts a novel and innovative approach to investigating the size of the effect between different characteristics of NBS, focusing on ecological domains and ecosystems services and adverse health outcomes in cities. Similarly, to Chapter 6, the analysis adopts the city as the unit of analysis triangulating statistical analysis of categorical data with multidimensional scaling and co-occurrence network analysis of qualitative data commentaries provided in the UNA. Studies based on aggregated data have been criticised for ecological fallacy and networked effects across populations (Steel and Holt 1996; Freedman, 1999). However, an understanding of the population-level impact of NBS is important for the governance of intra-city finance and urban planning investment decisions by state and regional actors (Bowen, 2013; Browning and Rigonlon, 2018) and the design of upstream approaches to impact on population-level trends (Rutter et al., 2017; Sneihotta et al., 2017).

Mortality patterns are determined by several different factors, including age, living conditions, surrounding environment, and lifestyle choices. All-cause and cause-specific mortality are important metrics in population health; data on the rate of, cause and numbers of deaths categorised by gender, age and location provide valuable intelligence for policy debate, conceptualisation and planning of interventions. However, across Europe, public health structures vary between and within countries, leading to variations in medical culture, institutional frameworks for reporting, sources of pathological data, and impacting the classification of disease in diagnosis (Lozano et al., 2013). Due to the uncertainty and potential bias associated with the cause of death assessments, some scholars are critical of mortality as a measure of the effectiveness of health systems (Allin and Grigon, 2014; Lavergne and McGrail, 2013). Despite these limitations, mortality indicators for cities published in the Urban Audit are one of the few pan-European health datasets available based on analysis of medical certificates of death classified based on the International Statistical Classification of Diseases and Related Health problems (European Union, 2018). Table 3-4 summarises the indicators from the UNA and Urban Audit that were analysed in this study.

Characteristics of NBS	Health outcome indicator
Type of ecological domain including parks, urban greenspace connected to grey infrastructure, external green buildings, blue spaces, allotments and community gardens, derelict or abandoned lots and green areas for water management	All-cause mortality
Type of ecosystems services including provisional, regulatory, habitat supporting services and cultural.	Mortality due to heart or respiratory disease
Modes of governance	All-cause mortality in females under 65 years
Type of non governmental actor	All-cause mortality in males under 65 years
Key actor involved in NBS	Infant mortality
Key actor instigating NBS	
Mode of participation	

Table 3-4 Characteristics of NBS and health outcome indicators used in analysis

To investigate the relationship between the differing characteristics of NBS and health outcomes, each characteristic of NBS and health outcome variable was categorised based on their frequency of occurrence in SPSS (version 24.0). Exploratory data analysis revealed count outcomes for some variables (e.g. infant mortality or some types of ecological domain) had distributions that are highly skewed towards the right with a preponderance of zeros. Aschengrau and Seage (2014) argues that by classifying count data into distinct groups, the researcher can examine the relationship between the outcome variable and the proportion of deaths due to each health outcome. Hence, count frequencies were categorised so that Pearson's Chi-Squared could be used to analyse the relationship between each characteristic of NBS and different health outcome indicators. To adjust for confounding variables, the analysis included the composite indicator for SEP (see section 3.2) based on analysis of educational attainment,

median income, poverty due to social transfers or low work intensity and EU-SILC data for occupation type. Since Chi-squared does not analyse the strength of the relationship between the variables, our study calculated Cramers v effect size to investigate the statistical significance of the result (Cohen, 1988; Sheskin, 2011). Due to concerns about the use of aggregated data in this study, the thesis engages with the politics of hybridity (Whatmore, 2002: Sui and DeLyser, 2012), utilising quantitative methods to analyse textual data (Lebart et al., 1991) to triangulate (Jick, 1979) the results.

Using KH Coder software (Higuchi, 2016), I deployed multidimensional scaling and co-occurrence network analysis to quantitatively analyse textual data published in the UNA. Like, PCA and MFA, Multidimensional scaling, a non-parametric, distance-based multivariate technique utilised to reduce data dimensionality and visualise the principal characteristics of 'other' type of ecological domains and ecosystems services, but also unpack the differing roles of actors involved in the governance of NBS and how they relate to health.

In this study, a quantitative approach was applied to analyse the content of textual commentaries using KH Coder (Higuchi, 2016). KH Coder is open-source software for computer-aided text analysis that enables measurement of constructs by processing text based on the frequency of words, quantitative content analysis, text mining and computational linguistics (McKenny et al., 2016). Text mining is broadly defined as a knowledge-intensive process that involves systematically analysing word use patterns, combining quantitative statistical and qualitative methods to extract meaningful information from unstructured data (Wang et al., 2018; Ignatow and Mihalcea, 2017). The complexity of natural language is a key challenge for text mining since words and phrases can have multiple meanings leading to ambiguity and noise within the extracted data (Gaikwad et al., 2014). There are several different text mining approaches that draw on linguistics, discourse analysis, content analysis, information retrieval, and artificial intelligence (see review Lebart et al., 2014; Gaikwad et al., 2014; Ignatow and Mihalcea, 2017). The thesis adopts a word-based approach to systematically reduce the flow and measurement of the frequency of different constructs of text (Roberts, 1997; Lebart et al., 2014; Humpreys and Wang, 2018; Wang et al., 2018). Firstly, tokenisation was undertaken to remove HTML tags, punctuation, abbreviations and stop words and

stemming was applied to identify common stem multiple words with similar meaning (e.g., green space, green space, urban greenspace).

Unstructured textual commentaries were then repeatedly read in parallel to the analysis of the distribution of co-occurring word frequencies and findings used to code text (Chapter 6) (Lebart et al., 2014; Ignatow and Mihalcea, 2017). To explore the structure of the data, multidimensional scaling (MDS) is a non-parametric multivariate technique (Krustal 1964) that is used to visualise the hidden structure of different underlying concepts by their data points onto a two dimensional statistical or concept map (Ignatow and Mihalcea, 2017). MSD is not an eigenvalue-eigenvectors technique like PCA or MFA and is a form of non-linear dimension reduction used originally developed in mathematical psychology that is also used in ecology and economics (see review Dexter et al., 2018). To compute MSD, KH Coder normalises the data using Krystal Stress-1 formula and calculates the measure of similarity or degree of co-occurrence between words. Concept maps are created to provide graphical representations of the proximity values calculated for each segment of coded text that enable the explore the pattern of clustering within the data and strength of the relationship between the concepts to be visualised (Vinerean et al., 2014; Yano et al., 2021). Quine (1980) argues that knowledge should be regarded as a network of structurally linked clusters and hence, this study also adopted co-occurrence network analysis which creates a net-like structure of the pattern of occurring words that appear together in the syntax's (Hemsley et al., 2016; Tang et al., 2018).

4 Distribution of nature-based solutions across Europe

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Highlights

- This study contributes to research that explores the relationship between the geographies of Nature-Based Solutions (NBS) and underlying social and economic factors that influence quality of life (QoL) across Europe.

- This study finds that while NBS are co-producing ecosystem services across multiple scales to regenerate socially disadvantaged communities, less than 6% aim to alleviate poverty, deprivation or tackle issues of unemployment and less than 25% relate to housing or neighbourhood regeneration.

- Accordingly, we suggest that NBS are more often used to address green-growth imperatives without considering the implications of historical and divergent social and economic inequalities in cities.

- The current use of the framework does not regularly embrace the diverse structural and historical inequalities in which it is applied or EU policy on economic convergence of member states.

- Failure to address these considerations could lead to cities reinforcing or even exacerbating inequalities within deprived communities, particularly in eastern and parts of Southern Europe, which could create issues of environmental injustice.

Abstract

Nature-Based Solutions (NBS) is a conceptual framework that seeks to use properties of nature to co-produce ecosystem services to build climate change resilience and improve quality of urban life by mitigating the relationship between health inequality and socio-economic adversity. This study investigates how the distribution of these forms of urban nature relate to trends in demographic change and social and economic indicators that influence material aspects of quality of life (QoL) in cities. Using macro-scale spatial mapping and descriptive pattern identification, we examine the relationship of distribution trends in the key characteristics of NBS across European cities and social and material factors that influence QoL. Our findings suggest that less than 6% of NBS aim to address poverty or deprivation and fewer than 25% relate to housing or neighbourhood regeneration. We argue inattention to the complex intersectional relationship of socio-economic disparities, historical structural conditions, and the impact of changes to the structural policy on economic convergence across regions leading to the concept being used to address green-growth imperatives in Western Europe rather than mitigate inequalities across eastern and parts of Southern Europe. Failure to address these considerations in the design and deployment of NBS could lead to cities reinforcing or even worsening inequalities within deprived communities, particularly in these areas.

4.1 Introduction

Greening the urban fabric with vegetated public space, often referred to as urban greenspace or green infrastructure, has been used as a strategy to improve the urban quality of life (QoL) since the nineteenth century following rapid industrial growth in many American and European cities (Eisenman, 2016). Greater awareness of the interaction between public health, urbanisation, climate change, and a reduction in the quality of and access to open space (Kabisch and van de Bosch, 2017) has led to greenspace increasingly being viewed as a right to urban living.

In parallel, a growing awareness of the role that nature-human interactions play in shaping our health outcomes (Ives et al., 2017; Cleary et al., 2017; Soga and Gaston, 2016) has influenced a shift in thinking about the role of nature in cities. Recent arguments declare that while some

believe society has stopped being a passive beneficiary of nature's services, careful management, use, protection, and restoration of urban ecosystems can provide multifunctional services to address societal challenges (Nesshover et al., 2017; Frantzeskaki et al., 2019; Cohen Shacham et al., 2017). Transnational actors (IUCN, 2012; EC, 2015) have accordingly looked for solutions capable of reimagining and redesigning socio-ecological-technical relationships in a way that can respond to and alleviate the mounting challenges of urbanisation and climate change while distributing the benefits equitably (Nesshover et al., 2017; Cousins et al., 2020). This has led to the emergence of a new discourse, Nature-Based Solutions (NBS). Whether NBS is an appropriate strategy to tackle persistent structural inequalities on the scale required to improve QoL in cities remains in question (Jennings et al., 2016; Michell et al., 2015).

The stark inequalities of access to high quality greenspace have been made abundantly clear to society through the recent social distancing measures implemented to contain the spread of Covid-19 (Goodier and Rayman, 2020). Despite growing evidence that NBS could potentially mediate against social and health inequalities (Mitchel and Popham, 2008; Mitchell et al., 2015), Wolch et al., (2014) argue that the distribution of good quality greenspace provided by NBS remains stratified according to economic and social characteristics. Richardson et al., (2013) argue that the persistent and further deepening of inequalities in access to green and blue space provided by NBS risk exacerbates the health effects of climate change, particularly among vulnerable groups. However, Rothenberg (2017) argues that municipalities often use such investments to stimulate green growth and revitalise neighbourhoods without considering the social equity component of sustainability, leading to missed opportunities to realise just transitions to sustainability and realise health benefits. Anguelovski (2015) argue this approach not only risks triggering marketisation and gentrification but can also lead to the reproduction of historical conditions and deepening structural inequalities that negatively affect health (Cole et al., 2019). Consequently, unpacking the relationship between structural inequality and the distribution of NBS is firmly reliant on understanding how the characteristics that form an NBS implementation (such as ecosystem services, type of green space and governance mode) relate to QoL across urban Europe.

Using an environmental justice lens (Scholsberg, 2003, 2004, 2007), this paper examines how the distribution of the key characteristics of NBS relate to underlying social and economic conditions that influence QoL across Europe using data published in the Nature Urban Atlas (UNA) (www.naturvation.eu, 2017). This paper contributes to debates surrounding the equitable distribution of NBS by exploring the relationship between NBS and the uneven geographies of QoL, taking into consideration how the distribution of the critical characteristics of NBS relates to the distribution of structural inequalities across Europe.

4.2 Understanding the role of Nature-Based Solutions in the transformation of Quality of Life in cities

4.2.1 What are Nature-Based Solutions?

Two main definitions of NBS exist. Firstly, NBS have been defined as "actions to protect, sustainably manage and restore natural or modified ecosystems, which address societal challenges (e.g., climate change, food and water security or natural disasters) effectively and adaptively, while simultaneously providing human well-being and biodiversity benefits" (p2, Cohen-Shacham et al., 2016). The European Commission also define NBS as solutions that are inspired by, supported by, or copied from nature to resolve societal challenges in sustainable ways that are cost-effective and build resilience (EC, 2015). Both definitions claim that NBS will contribute to transformative social change (Woroniecki et al., 2020) and draw together similarly framed concepts (such as ecosystem-based adaption) into an overarching framework. In doing so, the concept aims to reinforce relationships between them and encourage a transition from a resource-intensive to resource-efficient and inclusive, sustainable growth model (Faivre et al., 2017).

The role of NBS as a vehicle for social change has been challenged by some (Eggermont et al., 2015; Madanipour et al., 2014), with the entrepreneurial and market-based approach advocated by the European Commission cited as the main issue. Others have argued that exclusion of specific knowledge, a lack of definition and pluralistic framing could lead to unintentional inequitable distribution of NBS benefits (Pauliet et al., 2017; Woroniecki et al., 2020). Loughran (2020) argues that urban greening has a long history of being perceived by cities to

be a means to use ‘nature’ as a cultural fix to tackle social crises. Conversely, Almassy et al., (2017) describe NBS as unlike any existing greenspace examples because the functioning, governance or management has been transformed in some way to advance sustainability. Accordingly, many academics believe that if these solutions are used and managed carefully, they can re-integrate nature and natural processes into cities, as well as provide ecosystem services that improve QoL and stimulate economic growth, creating local job opportunities (Balian et al., 2016); Potschin et al., 2015). To address some of these debates, the EC Horizon 2020 project, NATUVATION, defined NBS as deliberate, physical or discursive interventions inspired by or supporting nature that seek to change or enhance the function of an area or structure to address societal challenges (Bulkeley, 2016).

4.2.2 Quality of life (QoL)

QoL is a spatially variable condition and a multidimensional construct that describes and evaluates the circumstances or conditions of life that people experience across different dimensions of society (Lopes and Camanho, 2013). The World Health Organisation (WHO) define QoL as “an individual’s perception of their life position in the context of the cultural and value systems in which they live, and in relation to their goals, expectations, standards and concerns” (p1405, WHO, 1995). QoL is influenced by internal psychological and physiological mechanisms that affect how people perceive and relate to their environment, daily routine, and external influences such as education, housing conditions and income that influence a given place or geographical settling (Pacione, 2003; Mensah et al., 2016).

An indicator of QoL can be constructed by using individual measures of contributing elements that relate to QoL's subjective and material factors (Land and Michalos, 2015). Quantitative measures of QoL are often more readily available than subjective indicators and, due to their relatedness, are often used as a proxy for citizens perceptions (Marans and Simpson, 2011). A further challenge of measuring QoL is the spatial dimension and whether this can be assessed appropriately at differing scales ranging from global to household. Augmenting the spatial measurement scale increases the risk of ecological fallacy by attributing average conditions to an entire population, potentially masking variations in inequality at smaller scales (Norman,

2010). Despite these limitations, Pacione (2003) believes that descriptive pattern identification and mapping at a macro-scale is still valid since it allows us to examine the relationship between the distribution of the critical characteristics of NBS across the landscape and the social determinants of capital accumulation. These determinants are spatially differentiated across Europe leading the EU to invest over €350 billion through its Cohesion Policy to stimulate economic growth, competitiveness and sustainable development in countries and regions that were less developed. By reducing the spatial variation in the uneven development across the landscape of Europe, the EU aim to improve QoL and strive for economic convergence (Ayouba et al., 2019). Lafuente et al., (2020) suggest that macro governance of economic policy has led to convergence based on groups of European countries, however, with similar socio-economic characteristics (referred to as the club convergence concept).

Regardless, Davies (2017) suggests that structural economic disparities remain high between many European nations. Many central and eastern European countries have a Gross Domestic Product (GDP) of less than 75% of the average. Consequently, this has magnified existing regional economic growth disparities and deepened structural inequalities (Beckfield, 2019; Lammarino et al., 2019).

4.2.3 Environmental justice

Radical environmental justice is a socially constructed pluralistic concept with a broad discourse encompassing maldistribution, procedural and participatory dimensions, justice as recognition and capability (Holifield et al., 2018; Scholsberg, 2004). It also extends to the complex interactions between each aspect of justice that are the product of expressions or configurations of power that regulate and order social, cultural and institutional practices (Harvey, 2009). Young (2009) also argues that citizens may suffer injustice due to structural inequality whereby the operation of structural processes operated by institutions conspire to limit access to resources, opportunities for well-being or constrain opportunities for self-development. Moreover, Young (2009) believes that structural injustice occurs due to complex interactions between the practice of institutional rules, hegemonic norms or incentives that combine with effects of past policies to reinforce existing inequalities. Structural injustice

shares several concepts across participatory, procedural, and distributive dimensions of justice. Distributive justices focus on the fair allocation of environmental 'bads' (such as poor air quality) and resources (such as access to greenspace and cultural ecosystem services) provided by NBS. At the same time, participatory and procedural dimensions relate to the meaningful involvement of people (Ayeman et al., 2004) in NBS monitoring, management, and governance. Another school of thought regarding environmental justice suggests it is more closely concerned with the underlying dynamics and causes of inequality at different scales (Walker and Bulkeley, 2009). In the context of this definition, we use quantitative indicators published by the UNA and Urban Audit to examine how the spatial distribution of the critical characteristics of NBS relates to the uneven geographies of QoL across Europe.

4.3 Methodology

This section provides an overview of the methodology adopted to examine the relationship between NBS and social, economic and health factors. It describes the sources of data that are available and the statistical profiling undertaken. Subsequently, it also addresses possible limitations.

4.3.1 The Urban Nature Atlas (UNA)

To help us understand how NBS foster innovation and enable sustainability transitions in cities, data on the innovative potential of different types of NBS, the type of innovation and their respective transferability and novelty was collected. The UNA includes binary categorical variables that describe the goals of the intervention and its key characteristics (such as the ecological domain, scale, and primary beneficiaries), and which also describe the forms of governance evaluation and learning for up to 10 NBS in 100 cities across Europe (Naturvation, 2017). Some textual commentaries accompany categorical variables to add context or further explanation regarding the variable in question. Data from the UNA was used to undertake statistical profiling to clarify and illuminate the main features of each of the variables in the database (section 3.3).

4.3.2 Eurostat Urban Audit

The Eurostat Urban Audit is one of the few QoL datasets (available on a pan-European basis) to include demographic, social, economic, environmental, training/education, and (for a limited number) health indicators. These indicators play a central role in capturing the everyday realities of poverty. They also serve to clarify the significance of confronting such poverty in several dimensions, including longevity, employment prospects (or lack thereof) and educational achievement. Poverty and deprivation can be associated with educational disadvantage, poor health, inadequate housing, and exclusion from the labour market.

To help illuminate how the pattern of distribution of the key characteristics of NBS relates to differing structural conditions and trends in material aspects of QoL across Europe, a pan-European analysis of descriptive characteristics, published by the Urban Audit (Eurostat, 2017), was duly completed. This analysis contextualises trends in urban growth (Brenner et al., 2000), educational attainment and employment opportunities (Sirgy et al., 2000). A pan-European approach enabled us to explore how the distribution of NBS relates to the uneven geographies of QoL. At the same time, it also facilitated an exploration of the pattern of European NBS, and of the relationships obtaining between structural conditions that have fostered inequality within the continent (Beckfield, 2019).

Data on each indicator are published for three spatial units: Functional Urban Area (FUA), Greater City and City (see Figure 4.1). The city is defined as the administrative boundary of the local authority where most of the urban population lives (approximately 50k inhabitants). The FUA, meanwhile, comprises both the city and its surrounding commuter regions. The Greater City signifies an approximate boundary of the broader extent of the urban centre as and when it extends beyond the administrative boundary (Eurostat, 2020). A review of the availability of indicators for each unit suggests that they vary in quality and quantity, by reference year and by city. The European Commission (2004) also report that municipalities define the spatial boundaries of the city, FUA and Greater City differently due to differences in the structure of local government. These differences make a comparison between cities more challenging, and hence, this study selects the FUA unit of analysis to minimise these effects.

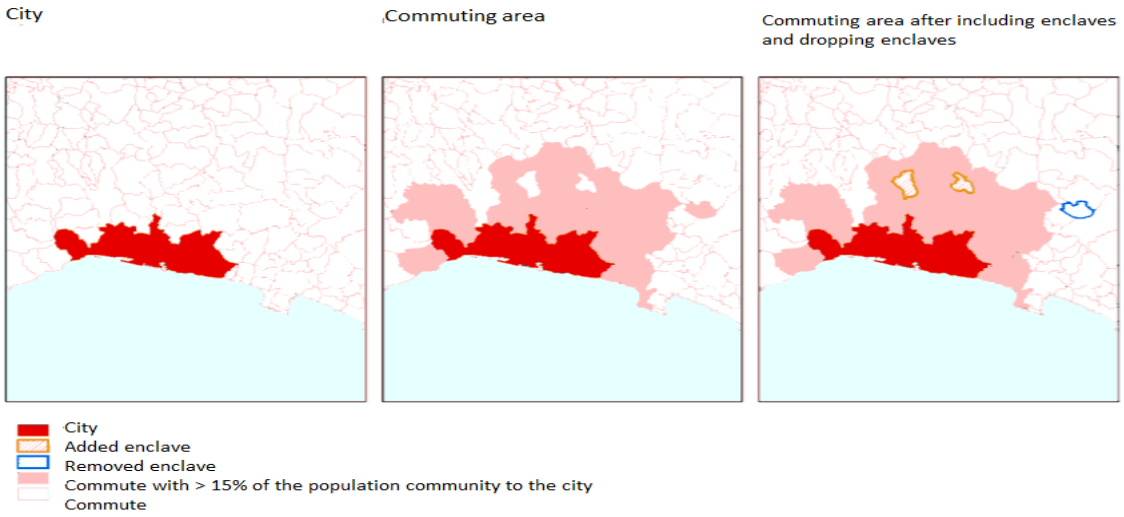


Figure 4-1 Definition of a functional urban area (source: European Union, 2017)

Figure 4.2 shows the distribution of 100 cities included in the analysis selected to reflect differing urban conditions across the continent. Additional criteria for selection included climatic vulnerability, proportions of green space, temperature, and proximity to rivers or coasts.

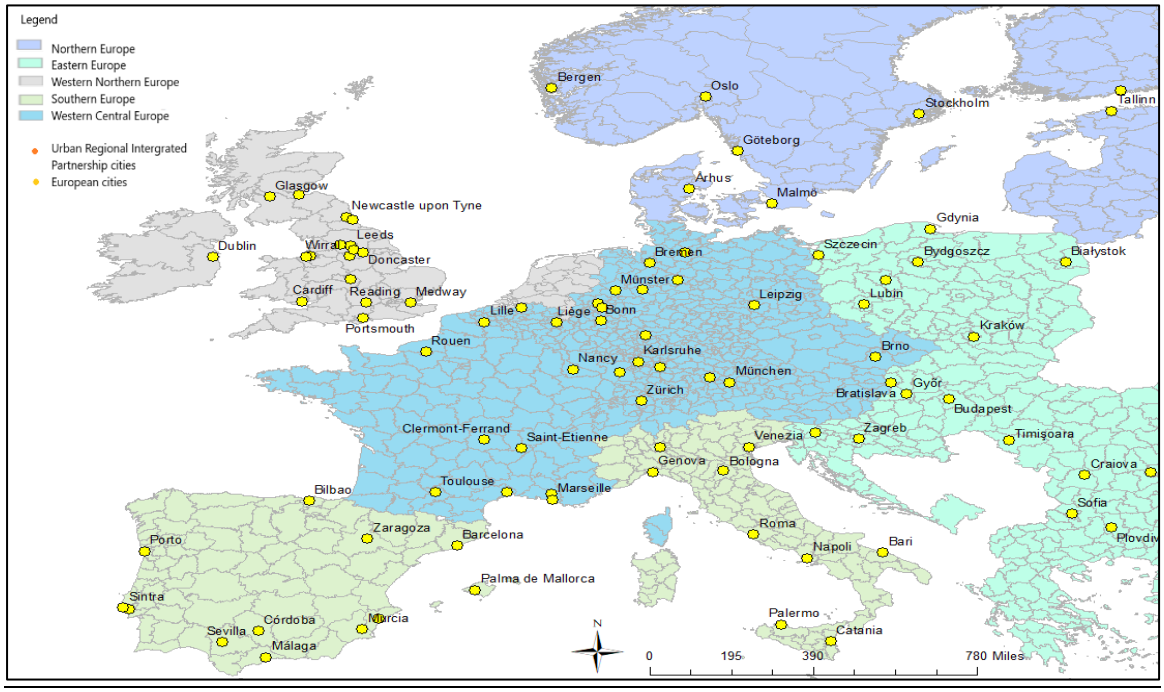


Figure 4-2 *Map of cities selected for analysis by the NATURVATION programme, including Urban Regional Innovation Partnerships (URIPs) (adapted from Almassy et al., 2017)*

4.3.3 Statistical profiling

At the outset, statistical profiling - using descriptive statistics - was undertaken to clarify the main features of each of the variables in the UNA and the Urban Audit, as produced by Eurostat. To illustrate the spatial distribution of each variable and whether these patterns changed temporally, graphical, and thematic map representations for each variable, using Arcview GIS, were created across Western, Southern, Northern and Eastern Europe (see Figure 4.2). Especially in terms of the reference years 2014 to 2017, data lacunae for several indicators were highlighted by the thematic mapping of indicators in the socio-economic and health categories. Analysis of documents published by Eurostat revealed that this was due to several methodological changes implemented in 2013/14 - changes that reduced the number of data variables but also led to the integration of others. An evaluation of each country's metadata indicated that a failure to update national censuses on the part of several states since 2011 might explain data absence in some respects (European Union, 2017). Furthermore, Eurostat had not begun collecting data for some indicators when some of the NBS was implemented, thus limiting data available for comparison. To overcome these limitations, the reference year used for statistical analysis is the year with the largest sample size, which will vary by indicator.

To clarify how the geographies of implementation of NBS relate to social and economic disparities across Europe, we classified each city included in the study into one of five subregions, based on the approach developed by Eikemo et al., (2008). Then, basic statistical profiling for each indicator in each sub-region was completed. However, because the distribution of cities across each region was uneven, it was necessary to normalise the results using weighting factors shown in Table 4-1 (https://www.itl.nist.gov/div898/ handbook/pmd/ section6/pmd634.htm, 2017).

European sub-region	Number of NBS	Weighing Factor
Eastern	189	0.97
Northern	72	0.37

Southern	215	1.10
Western (Central)	268	1.37
Western (North)	232	1.19
Average	195.2	

Table 4-1 Weighting factors applied to each European sub-region to normalise the distribution of NBS

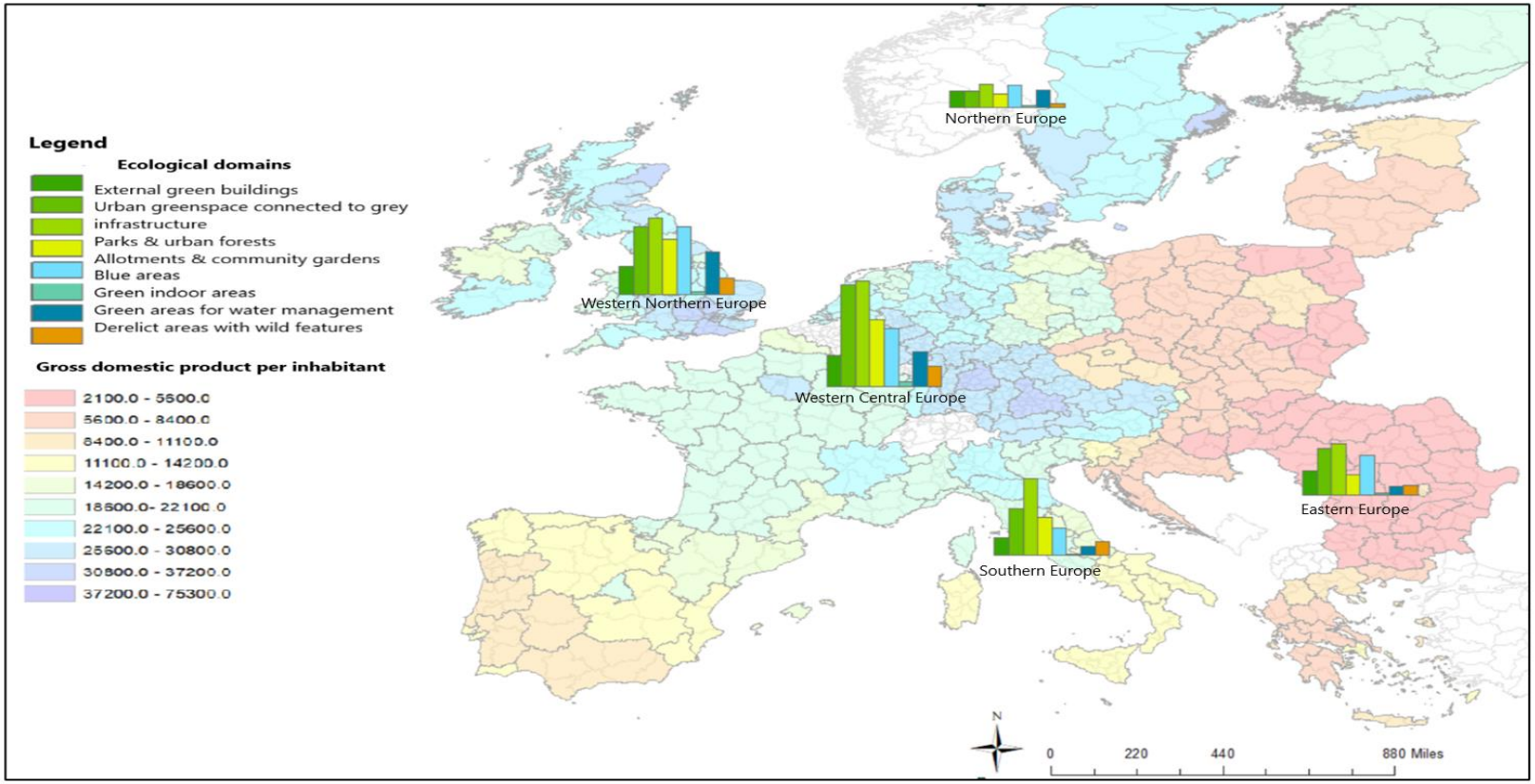
4.4 Results

4.4.1 Characteristics of Nature-based Solutions

4.4.1.1 Urban settings of NBS

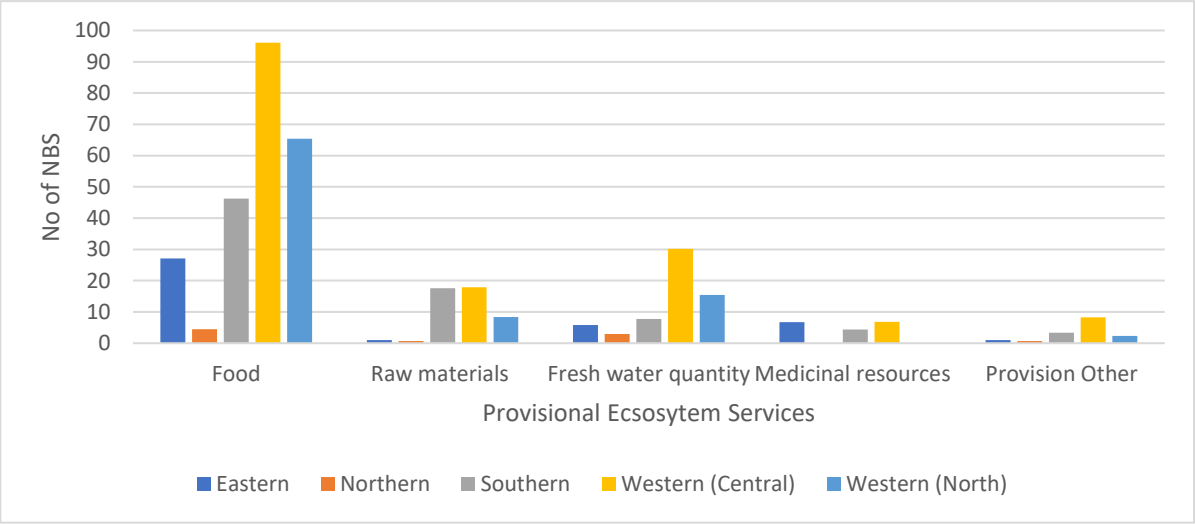
Following an analysis of the literature pertaining to green and blue spaces and their respective typologies, a classification of the 976 NBS published in the UNA was undertaken by Almassy et al., (2017), who categorised NBS into eight types of 'ecological domain'. The categories of ecological domain included: external green buildings (e.g. green roofs and green walls); urban green areas connected to grey infrastructure (such as green alleys or green playgrounds); urban parks and urban forests; allotments and community gardens; green indoor areas; blue areas (such as seacoasts or wetlands); green areas for water management (including rain gardens, swales and sustainable urban drainage systems); and derelict areas or abandoned spaces with patches of wilderness. Based on analysis of the sample of NBS published in the UNA (Naturvation, 2017), approximately 45% of these are categorised as urban parks, forests or urban green space connected to urban infrastructure. An additional 30%, meanwhile, are comprised of various forms of blue space or different types of community garden or allotment (Figure 4.3). Evidence suggests that 75% of NBS included in the UNA incorporate up to two types of ecological domain in their design. Three or more such domains, conversely, are included in fewer than 25% of these NBS. The latter is primarily located in Western and Southern European cities but are mainly absent from Eastern European cities, characterised by a lower proportion of urban greenspace (Kronenberg et al., 2020). Eastern European conurbations also typically evince a lower per capita gross domestic product (Figure 4.3).

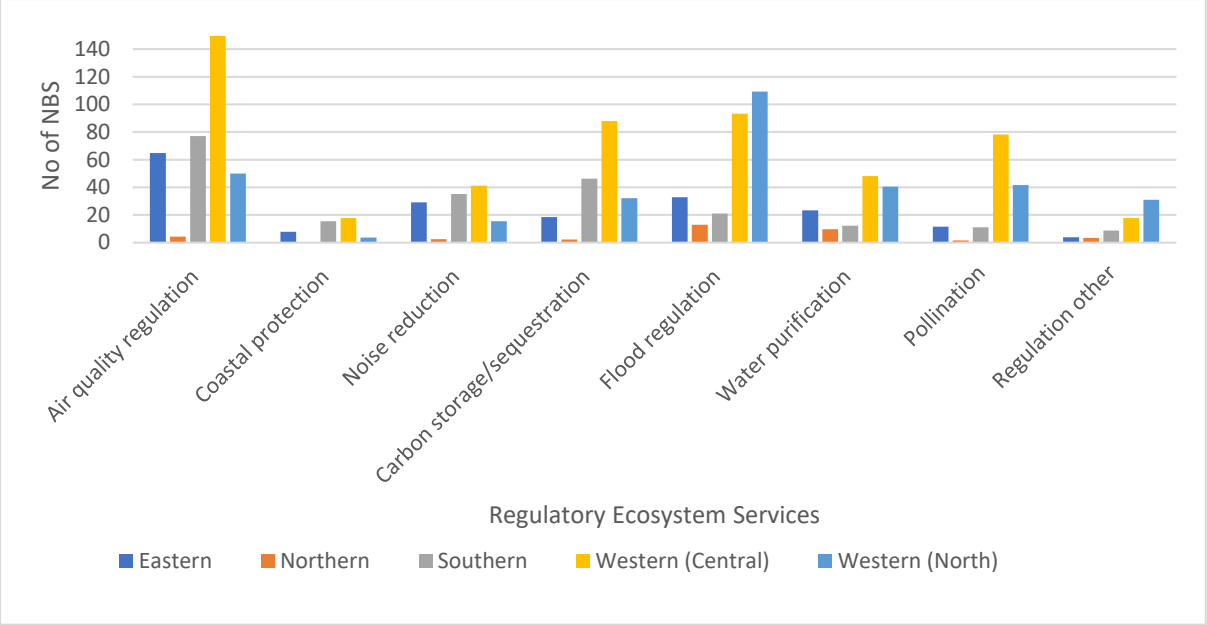
Figure 4-3 *Distribution of ecological domains and gross domestic product across Europe*

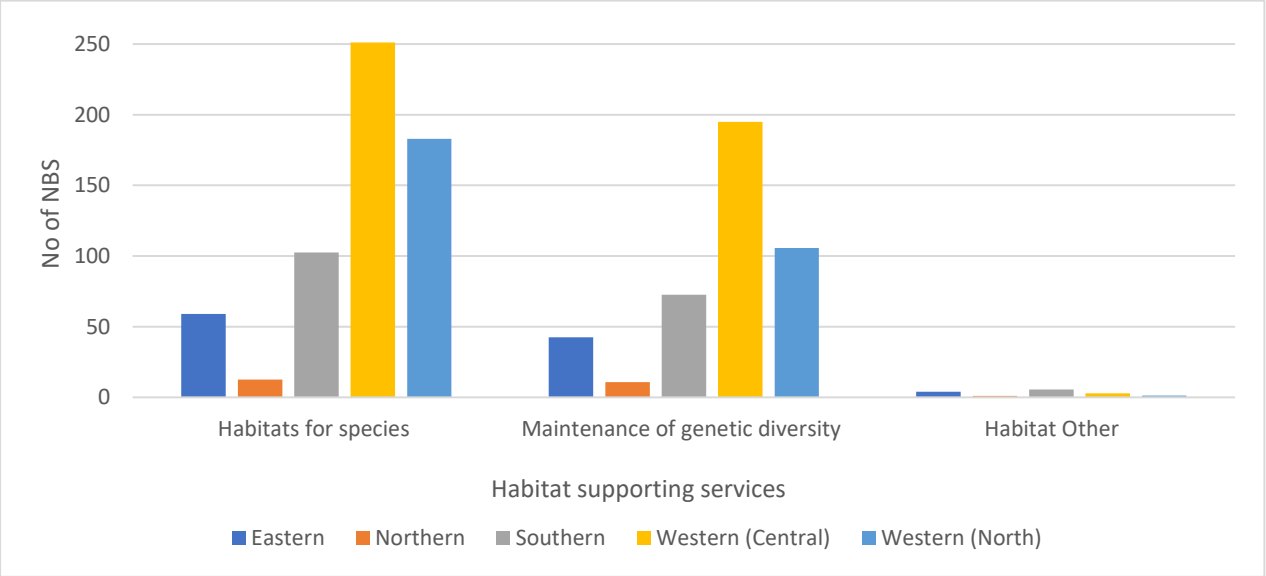


4.4.1.2 Ecosystem services

Naturvation applied the TEEB (Economics of Ecosystems and Biodiversity) classification of ecosystem services (MEA, 2005) to determine the type of services provided by an NBS. These might include provisioning and regulating services, habitat and supporting services, and cultural services. Analysing the relationship between the number of ecological domains and the type of ecosystem service per NBS revealed that 88% of the NBS provided cultural-ecosystem services (see Figures 4.4 a to d). Among these, one could find services pertaining to mental and physical health, or recreation, aesthetic appreciation, or services for tourism. Conversely, only 30% of the NBS provided provisional ecosystem services (e.g., urban food production or raw materials). Habitat-supporting services (such as habitat creation) and regulatory services (such as regulation of air or noise pollution) were provided by 54% and 58% of NBS, respectively.




No of NBS
140
120
100
80
60
40
20
0
Air quality regulation
Coastal protection
Noise reduction
Carbon storage/sequestration
Flood regulation
Water purification
Pollination
Regulation other
Regulatory Ecosystem Services
Eastern
Northern
Southern
Western (Central)
Western (North)


No of NBS
250
200
150
100
50
0
Habitats for species
Maintenance of genetic diversity
Habitat Other
Habitat supporting services
Eastern
Northern
Southern
Western (Central)
Western (North)

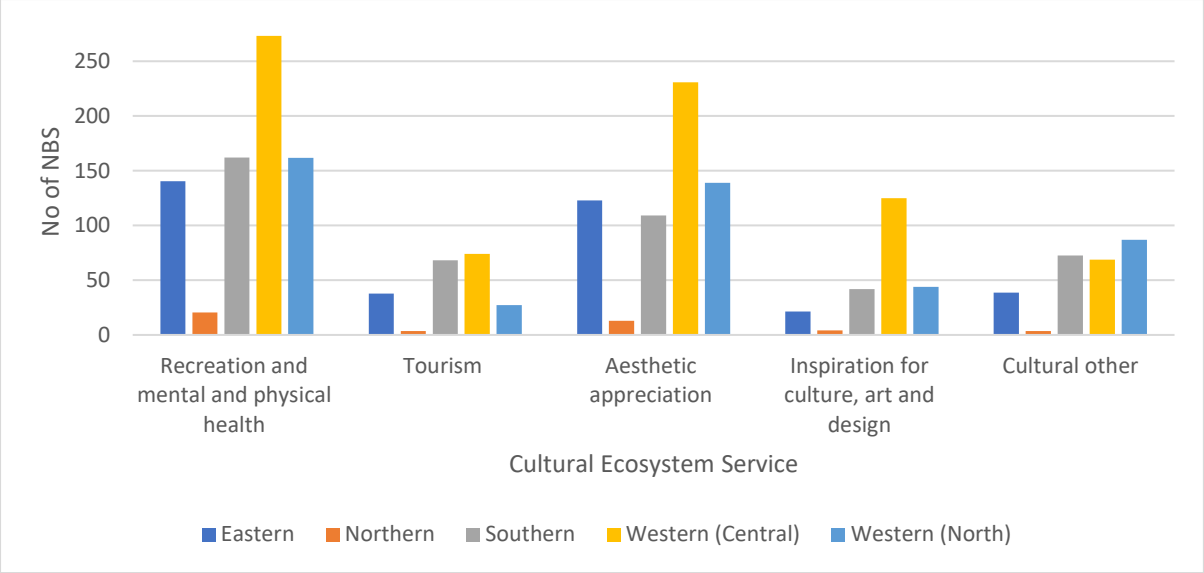


Figure 4-4 a to d distribution of provisional, regulatory, habitat-supporting and cultural-ecosystem services across each European Region (based on the sample of NBS published in the UNA)

The present study's findings indicate that multifunctional NBS (Pauliet, 2017; Franzteskaki, 2019), characterised by the provision of a diversity of ecosystem services, are concentrated primarily in Western European cities. Here, 47% of NBS provided three or more ecosystem services, such as regulating climate, noise, or flooding, or producing food. In this study, we define multifunctional NBS as those that have three or more ecosystem services. Figure 4.5 shows that Western and Southern Europe have the highest proportion of multifunctional NBS, as evinced by the distribution of NBS that claim to provide multifunctional ecosystem services. A more detailed analysis of the relationship between the frequency of different types of ecosystem service (on the one hand) and ecological domains suggests there is no clear evidence that an increase in the number of ecological domains leads to an increase in the number of the different types of service.

Conversely, due to inadequate data availability, this analysis consciously did not address data pertaining to 'disservices' provided by NBS. (In other words, the characteristics or functions of ecosystems that generate consequences perceived to be undesirable or injurious.) Similarly,

examining the relationship between the frequency of each type of ecosystem service and the scale of NBS does not seem to indicate that scale of implementation influences the number of ecosystem services created by an NBS.

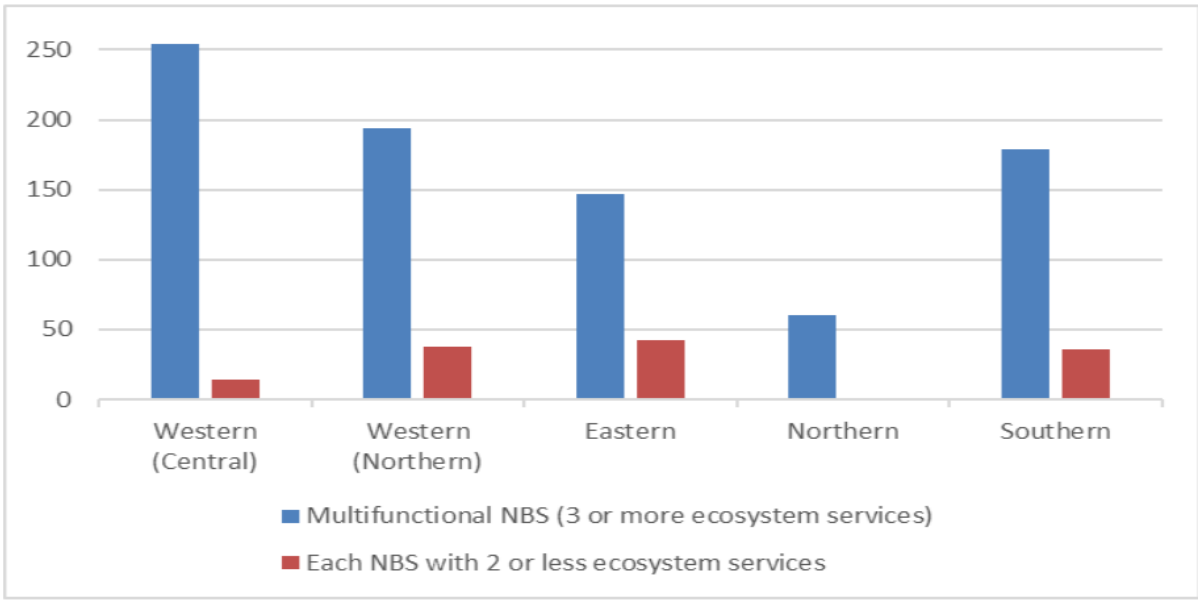


Figure 4-5 *Distribution of multifunctional NBS across each European Region (based on the sample of NBS published in the UNA)*

4.4.1.3 Governance Arrangements and Mode of Participation

The NBS governance process across Southern, Eastern and Western Europe predominantly has a hybrid or co-operative setup involving state and non-state actors in management decisions and decision-making processes. Hybrid governance accounts for 45% of NBS in the UNA, with the remainder divided between government, led (28%) and self-governance (26%), where non-state actors play a leading role in the operation process of projects. Our results show that although hybrid or co-operative governance arrangements between government and non-state actors (such as private companies, civic society, research, and community groups) occur throughout the life cycle of NBS from co-planning, management through to information dissemination. However, only 12% of these NBS involve society through oversight or

management of projects or involvement in monitoring, evaluation, or citizen science (Figure 4.6).

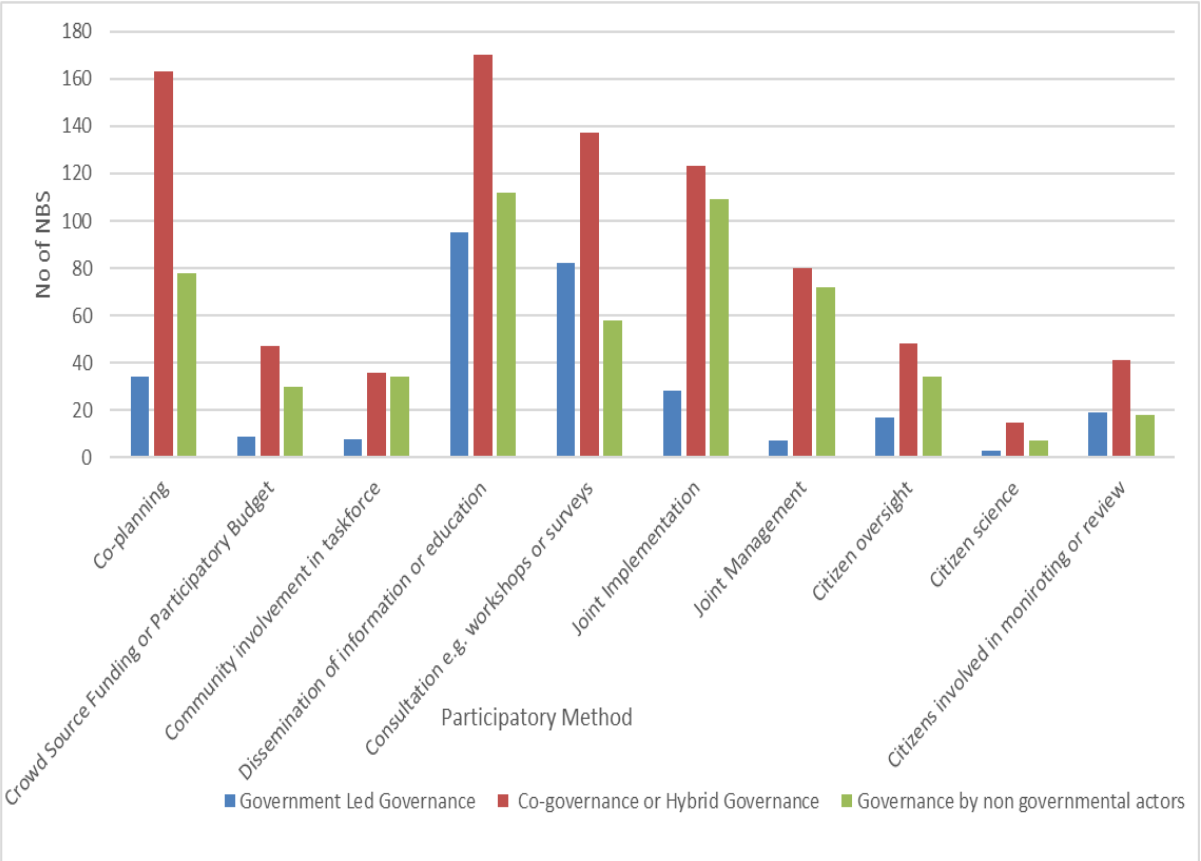


Figure 4-6 *Relationship between mode of governance and participatory method deployed by NBS*

Similarly, NBS, led by state actors or self-governed by private companies, civic society, or research institutions, focus on tokenistic efforts to engage stakeholders such as consultation or information dissemination with only 13% and 10% of projects delegating oversight or monitoring and evaluation to citizens, respectively.

4.4.1.4 Financing NBS – Total Cost, Sources of Funding and Financial Instruments

Collecting consistent cost data of the NBS was challenging for Almassy et al., (2017) and resulted in 35% of NBS in the UNA missing this data. Based on available data, 15% of NBS

cost less than €100,000, 20% cost €100k – 2M and 28% cost over €2M. In over 50% of cases, funding for NBS was sourced from public local authority budgets, while only just over 15% were funded by corporate investment, national or regional budgets, or European funds.

Figure 4-7 Comparison of the distribution of the total cost of NBS and GDP per inhabitant Spatial scale of NBS

4.4.2 Scale of NBS

To investigate the relationship between scale and pre-existing economic and social conditions across the urban landscape, each NBS was classified based on the scale of implementation

within the landscape. Four scales were used: macro-scale (global, continental, or national), mesoscale (regional, metropolitan and urban level), micro-scale (implemented at district or neighbourhood level) and sub-micro level (street scale). Results demonstrate that nearly 75% of NBS are implemented at a neighbourhood (42%) or street scale (33%), with just 18% implemented on a mesoscale.

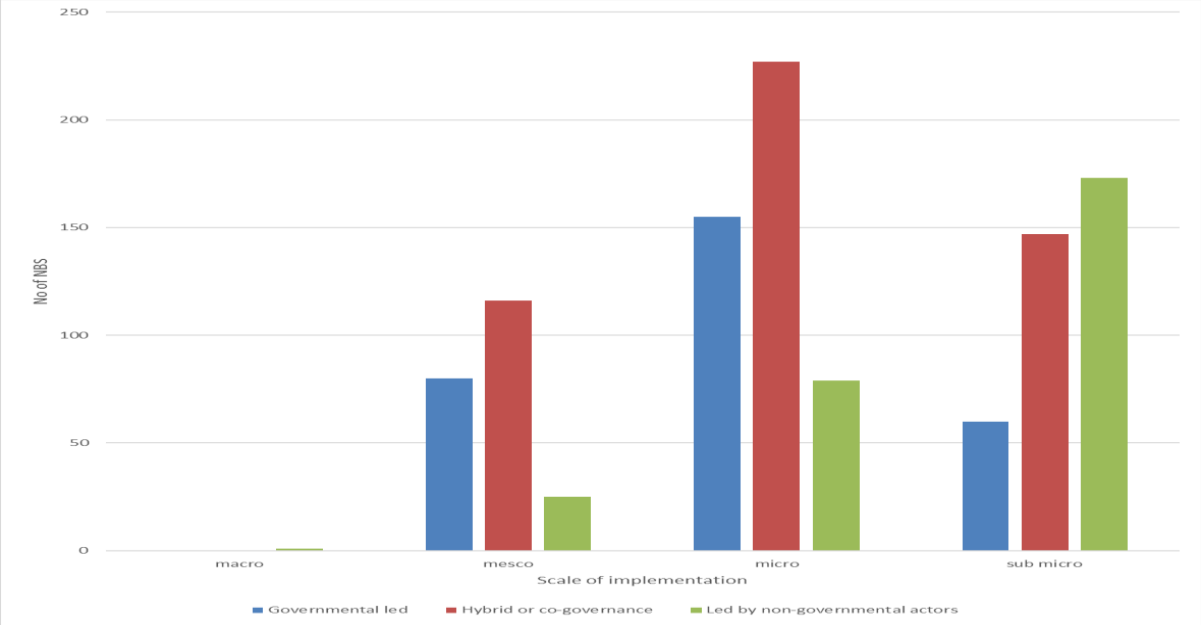


Figure 4-8 Comparison of the distribution of the total cost of NBS and GDP per inhabitant

8% of NBS implemented across multiple scales, such as at micro and sub-micro scale or micro and mesoscale. In Western European cities, sub-micro scale NBS are primarily governed by coalitions of private and public actors, whereas micro-scale interventions are primarily self-governed by non-governmental actors. In contrast, Southern European cities tend to have coalitions governing NBS at a micro-scale, while Eastern European cities have coalition governance at both micro and mesoscale.

4.4.3 Urban Forms of Innovation

Analysis of the distribution of different modes of urban innovation fostered by NBS suggests that many projects have primarily focused on technical and some forms of social innovation.

57% of NBS is accounted for by technical innovation, with western and southern European cities providing a broad range of ecosystem services, albeit at low frequency, through infrastructure and product innovation. More ecosystem services, mainly cultural services, are provided through social governance and cultural innovation NBS, accounting for approximately 40% in the UNA. Less than 30% of NBS use urban nature to deliver novel public policy (such as new regulations or incentives), economic frameworks, or systems innovations that lead to systematic changes in socio-ecological-technical systems.

Frequency of type of ecosystem service	Type of Technical Innovation			Type of Social Innovation				Systems Innovation
	Product	Process	Infrastructure	Policy	Economic	Governance	Cultural	
Provisional ecosystem services								
0	17.5	5.5	24.0	4.5	2.3	11.9	11.9	3.3
1	4.7	1.8	6.0	1.0	1.2	7.4	7.4	1.5
2	1.0	0.4	0.6	0.2	0.3	0.8	0.8	0.0
3	0.3	0.0	0.0	0.0	0.1	0.4	0.4	0.1
Regulatory ecosystem services								
0	4.7	1.3	8.5	1.6	1.6	8.1	15.1	1.0
1	5.6	2.8	8.6	0.5	0.5	5.4	8.0	1.0
2	4.5	1.9	6.0	0.9	0.9	2.6	3.8	1.0
3	4.3	0.8	4.2	0.5	0.5	2.6	2.2	0.8
4	3.7	0.8	2.5	0.1	0.1	1.4	1.3	0.1
5	0.6	0.1	0.7	0.2	0.2	0.4	0.3	0.7
6	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.2
Habitat ecosystem services								
0	9.5	1.7	10.3	1.4	1.8	7.7	11.9	1.2
1	8.2	3.2	12.5	2.0	1.0	6.8	9.4	2.2
2	5.8	2.8	7.7	2.3	1.0	6.0	9.2	1.5
3	0.0	0.1	0.1	0.0	0.0	0.0	0.1	0.0
Cultural ecosystem services								
0	2.7	2.9	4.8	0.7	0.3	1.8	1.3	0.1
1	6.0	1.7	6.8	1.0	0.9	5.3	7.1	1.0
2	8.6	1.7	9.2	1.7	1.1	6.4	10.3	2.6
3	4.6	1.1	7.9	1.4	1.3	4.8	8.2	0.6
4	1.4	0.3	1.8	0.6	0.2	1.7	3.4	0.5
5	0.2	0.0	0.1	0.2	0.0	0.4	0.3	0.1

Table 4-2 The relationship between the percentage proportion of the type of innovation and the frequency of multiple types of different ecosystem services. This is based on a cross-tabulation of the frequency of each type of ecosystem service and type of innovation. Percentage contributions of less than 0.9% are in grey.

4.5 Relationship between the distribution of NBS and variation in social and economic conditions across Europe

This section explores the relationship between the different characteristics of NBS and key trends in demographic, social, and economic indicators using quantitative indicators relating to QoL aspects.

4.5.1 Population trends

There are considerable intra-city differences in the median populations across the sample cities of the UNA. Improvements in adult mortality and falling birth rates have increased median age, leading to growth in elderly populations, especially in Southern and Eastern European cities characterised by lower GDP and greater risk of poverty or social exclusion. Meanwhile, a growing young population through re-urbanisation is being seen in Northern and Western Europe. Despite these two trends, our analysis demonstrates that only 6% of cases in the UNA include specific targets, goals or implementations relating to the elderly and/or to children. These results are surprising given the rise in maximum daily temperatures and humidity in recent years and the vulnerability of children and the elderly to adverse health effects associated with extreme temperate and humidity. Furthermore, only 34 solutions were in parts of Western central, Southern or Eastern Europe that experienced record-breaking daily temperatures in 2003 and 2015.

4.5.2 Housing Deprivation

Overviews of housing standards across Europe suggest that the quality and composition of housing tenure is unevenly distributed throughout Europe, with a distinct gradient in housing quality observed from east-west and south-north (Fernandez-Carro et al., 2015). These differences relate to the legacy of different approaches to housing provision, including the legacy of state control over housing in Eastern Europe leading to privatisation of social dwellings and the role of the family in housing provision in southern Europe (Mandic and Cirman, 2012). Such differences make it challenging to compare structural housing indicators reliably. However, regardless access to good quality housing is the main factor in measuring material deprivation and social inclusion, according to Nolan and Whelan (2011).

Despite evidence of the relationship between housing deprivation, access to greenspace and health inequality in cities (Wolch et al., 2014; Jennings et al., 2016), less than a quarter of cases in the UNA discuss the creation or adaption of existing urban greenspace as part of a new housing or neighbourhood improvement project, or adaption of existing grey infrastructure to incorporate greenspace such as green alleys, street trees or pocket parks. Where improvements in access and quality of greenspace are being made, their distribution patterns do not correlate with patterns of quality and composition of housing tenure across Europe.

4.5.3 Risk of poverty or social exclusion

There are several dimensions of poverty, including monetary poverty – cases where disposable income falls below the poverty threshold (60% of the national median) after social transfers, very low work intensity – defined as the number of people living in a household that work less than 20% of their potential working hours, and severe material deprivation (European, 2018). In Europe, 23.5% of the population are at risk of social exclusion or poverty due to one or more of these dimensions, with monetary poverty affecting 10-40% of the total population. This has a detrimental effect on the standard of living but can also influence the ability of citizens to participate in different economic, social and cultural activities. Despite this, analysis of the description and goals of the NBS in the UNA suggest less than 23 projects, of which 75% are located in Western European cities, aim to alleviate poverty, deprivation or provide

employment opportunities. Similarly, in southern and eastern European cities, only 8 NBS in the UNA aim to create job opportunities or resolve deprivation issues despite an even greater prevalence of social inequality.

4.5.4 Economic growth

Analysis of the UNA suggests that cities are using around 13% of cases in the UNA to achieve sustainable development goals for economic growth, while over half are being used to regenerate urban environments, mainly in Western and Southern Europe. Despite these claims, creating job opportunities through economic development was important in less than 30 cases in eastern European cities where GDP is less than €16,000. Furthermore, analysis suggests that the pattern of distribution of NBS that co-produce a range of ecosystem services are more prevalent in high income, innovative economy cities of western Europe where tertiary employment accounts for up to 40% of jobs. Economies that could benefit most from opportunities for green growth are those with a low GDP and high volume of jobs in manual labour, such as mining, agriculture, and manufacturing, prevalent in eastern Europe. Despite this, many of those cities fail to design NBS that are multifunctional and can facilitate job creation and improved sustainability.

4.6 Discussion

4.6.1 Distribution of NBS across Europe

There are significant socio-economic disparities across Europe. Some areas are experiencing stagnation due to changing population demographics, deepening interregional inequalities, and a lack of structural change, while others are undergoing rapid growth (Davies, 2017). In parallel, human interference with the climate system and endless pursuit of a growth-based paradigm has led to multiple global impacts, including unprecedented species extinction rates, rising global inequality in the wake of the 2008 financial crisis and more recently, the advent of the Covid-19 pandemic (Forster et al., 2021). In recognition of the urgent imperative to transition to sustainability and attend to these challenges, NBS has emerged, pledging to address a myriad of ecological, social, and economic challenges by working with urban nature in an integrated way to create multifunctional ecosystems that will improve people's QoL

(Raymond et al., 2017; Pauliet, 2017). Other scholars are critical (e.g., Loughran, 2018; Hicknel, 2018; Swygedouw and Heynen, 2008), positing the transformation of outdated infrastructure for economic growth while advancing sustainability by interweaving green-blue space into the urban landscape is a misguided objective if not an impossible task. Despite these critiques, transnational actors such as the World Bank and the European Commission argue that NBS 'refocus' the traditional ecosystem services approach from biodiversity principles towards a more human-centric approach, focusing on factors such as poverty alleviation and socio-economic development (Eggermont, 2015). However, the promotion of NBS as 'green saviours' may be overstated, with Sekula et al., (2021) believing that in reality, they are more likely to become a barrier to improving QoL, arguing it is impossible to distribute the benefits of NBS equally throughout society. In order to investigate factors influencing QoL and structural inequality in cities and how this relates to the distribution of NBS, we ran descriptive analysis and thematic mapping of objective demographic change, social and economic indicators published by Eurostat with key characteristics of NBS in European cities.

Building on the study by Almassy et al., (2017), this paper examined how the distribution of different types of NBS and ecosystem services relate to geographies of uneven regional development across Europe. Despite the prevalence of poverty, social exclusion, and divergence in GDP across the Eurozone, multifunctional NBS consisting of several ecological domains are mainly located in Western Europe. Of these multifunctional NBS, few co-create the full range of ecosystem services to build resilience among vulnerable communities and support ecological integrity as advocated by the definition of NBS (Cohen-Shacham et al., 2016). Our analysis shows multifunctional NBS are predominantly creating regulatory and cultural ecosystem services, but many do not co-produce provisional and habitat-supporting services. This is particularly apparent in some Southern and Eastern European cities where, despite having the most significant proportion of citizens at risk of social exclusion and poverty, have few ecosystem services co-produced.

The trends reported in our study are also reflected in disparities across the intra-eurozone (Beckfield, 2019), with the largest GDP per inhabitant receiving the most significant proportion of funding for NBS. Fligstein (2008) argues that frontier economies may be better placed to

perform better due to their shared understanding of the policy domain or field and mobilise social and cultural capital to help secure access to research funding (Bourdieu, 1986). We argue that this enables some cities to engage with research structures and cultures more effectively and leverage finance from the public, private and community spheres through social networks. In comparison, transition economies mainly rely on local authority and European funding to finance NBS, suggesting a lack of cultural capital due to a decline in vocational and business training following entry to the common market (Kogan et al., 2011). Our findings demonstrate a disconnect between the operational practice of NBS and European policy on convergence, ultimately leading to unfair distribution of the NBS benefits and reproduction of structural conditions within transition economies. This leads to frontier economies being rewarded financially, causing issues of distributive injustice, and leads to structural injustice as resources, opportunities for education and skills development are concentrated in more advantaged regions of Europe.

The distribution of forms of innovation deployed by NBS also reflects these trends with examples of technical, social governance and cultural innovation most common in Western Europe. This suggests that the region is more advanced in its attempt to transform to sustainability through the deployment of NBS. Critics suggest that such a transformation is more a historical consequence inherent of neoliberal urban restructuring that has followed retrenchment of the welfare state (Rosol, 2010; Swynedouw, 2005). Not only has this led to responsibilities traditionally managed by the state transferring to community actors, but also entrepreneurial strategies being implemented to secure alternative sources of finance and labour in the wake of further austerity (Whitten et al., 2019) under a pretence of an urban greening agenda (Jokinen et al., 2018). There is also a suggestion by Phillips et al., (2015) that this may indicate corporate or policy actors focusing on an idealised or political imagined version of the role that NBS can play in transitioning to a sustainable future.

According to our findings, many NBS appear to foster transformative governance arrangements encouraging a collaborative approach between civic society, state, and non-governmental actors. Few, however, engage with disadvantaged groups or mobilise citizens as agents of urban nature through oversight, monitoring, or citizen science activities even though

the ECs research agenda for NBS advocates citizen-driven innovation and empowerment to strengthen economies and 'capitalise' on NBS (EC, 2015). It is also less common to see innovative social policy arrangements as part of the deployment of NBS. Coriera et al., (2018) suggest these trends reflect patterns in innovation performance across Europe whereby Southern and Eastern European economies lag their Western European counterparts due to a reliance on European or foreign investment and a lack of skilled labour.

4.6.2 Relationship between the distribution of NBS and factors that influence quality of life (QoL) in European cities

Analysis of the relationship between the factors that influence urban QoL and distribution of the differing characteristics of NBS suggests that these solutions are inequitably distributed. Our findings show this is particularly evident in Eastern Europe, where GDP per inhabitant is significantly lower (Figure 4.7), and the risk of poverty or social exclusion is higher than in other parts of Europe. Furthermore, NBS consisting of several different ecological domains and three or more ecosystem services, are mainly found in Western Europe, suggesting that the distribution of the benefits of NBS is an issue of environmental justice.

In comparing the relationship between population growth and the distribution of NBS, the decline in the age of urban populations in peripheral cities (Lang, 2015) is not a key driver influencing the implementation of NBS. Analysis of cities with stagnant or an increasing average age of residents included in the sample suggests few NBS are designed to help ageing populations cope with climate change inflicted health issues. However, these divergent trends in demographic change pose significant challenges for cities in delivering 'friendly for all ages' service provision. For example, despite increasing evidence of the modification of heat-related all-cause mortality by urban green space and proximity of blue spaces (Burkart et al., 2016), only 34 NBS were located in parts of Europe that experienced record-breaking maximum daily temperatures that led to elevated heat-related mortality in 2003 and 2015 (Muthers et al., 2017). Our study demonstrates that vulnerable groups such as children and the elderly could be at greater risk from heat-related mortality than other age groups, providing further evidence of entrenched inequality in NBS environmental policy. Hence, we agree with Buffel et al., (2012)

that cities, particularly shrinking or rapidly growing young cities, should pay greater attention to the needs of an increasingly elderly or growing young population when designing NBS.

Another issue that has not been adequately considered in the conceptualisation and deployment of NBS is the gradient of housing quality and quantity across Europe. Housing deprivation is often assumed to accumulate insufficiencies in primary housing conditions, including inadequate construction, poor amenities, and insufficient space (Townsend, 1979; Palvarini and Pavolini, 2010). However, it is also an essential determinant of health, directly affecting it and indirectly influencing the quality of the surrounding area and material living standards. Accordingly, it is one of the key items in the household budget (WHO, 2014). Our analysis shows that less than 25% of cases relate to new housing or neighbourhood regeneration despite the evidence of a social gradient in housing quality and composition across Europe. Furthermore, where improvements in access and quality of greenspace are being made, their distribution pattern does not reflect the gradient of housing inequality or the prevalence of severe deprivation in parts of Europe.

Our study suggests that only 23 of the 976 UNA cases are being used as a policy intervention to address place-based inequality distribution in European urban centres. At a macro-scale, this evidence demonstrates that income and growth are the main drivers of the distribution of these intervention characteristics rather than material or structural inequalities. Our analysis shows that creative, more affluent cities with a substantial innovation capacity (Florida, 2004) secure a more significant proportion of funding to help mitigate against the effects of climate change and urbanisation. These findings are consistent with work by Rosol et al., (2017), who suggests that cities use frameworks such as NBS to justify spatially and socially selective 'greening' city strategies that rarely target deprived communities or disadvantaged residents to improve their QoL. Consequently, we believe the inattention to the existence of historical inequalities and nexus between access to greenspace, housing deprivation, and health inequality in cities by state and municipal actors involved in the development of environmental policy, strategies, or regulatory incentives to support the implementation of NBS confounds evidence of and risks reproduction of distributive and structural injustice.

4.6.3 Limitations of the study

This is one of the first studies to analyse the distribution of the characteristics of NBS and how they relate to the uneven geographies of QoL across European cities. To achieve this, we analysed large multi-block datasets, which presented challenges due to limited data availability. In the case of the UNA, language barriers, timescale of data collection and availability of referenced material for analysis affected the accuracy of the indicators. While the Urban Audit is one of the few pan-European datasets for cities that includes social, economic and health outcome data, it is provided by member states voluntarily, which ultimately affects its spatial coverage, quality, and reliability. Another key limitation of this study is the level of aggregation embedded in macro-region analysis. This may mask variations in both the distribution of the characteristics of NBS and inequality within and between cities and between neighbourhoods.

4.7 Conclusion

In this study, we have explored the relationships between the distribution of NBS and the social, economic and demographic factors influencing QoL across Europe. We have shown emerging evidence that some NBS are co-producing ecosystem services across multiple scales to address green-growth imperatives and regenerate socially disadvantaged communities at micro and sub-micro scales, particularly in Western Europe. However, while some multifunctional NBS are beginning to emerge, an increase in the number of domains does not translate into an increase in the functionality of the NBS that could help address broader sustainability challenges. Our analysis shows that the combination of divergent demographic trends and lack of access to adequate resources to meet the basic needs for an adequate QoL in some cities does not influence the distribution of NBS. These findings are surprising given the rhetoric surrounding the potential of NBS to stimulate economic growth and the drive for economic convergence.

There has been a failure to target NBS deployments and investment in cities where a lack of essential resources severely impairs resident QoL. We believe this is due to failure to consider the complex intersectional relationship of socio-economic disparities, pre-existing historical structural conditions, and the impact that changes to structural policy have had on economic

convergence across regions with similar socio-economic characteristics. This ignorance of pre-existing structural inequalities and the regional disparities in economic growth in the targeting and prioritisation of NBS makes it laissez-faire both economically and morally, creating issues of structural and environmental injustice.

Failure to address these considerations could lead to cities reinforcing or even exacerbating inequalities within deprived communities, particularly in Eastern and parts of Southern Europe, creating issues of environmental injustice. We have presented evidence that shows that the distribution of NBS is primarily based on income, with creative, more affluent cities securing a more significant proportion of the finance to implement multifunctional NBS across multiple scales. These findings support existing claims that these solutions have been used as a 'sugar coat' strategy to revitalise neighbourhoods and attract investment leading to a deepening of inequalities and triggering marketisation and gentrification of NBS (Anguelovski, 2015; Steel, 2018; Slater, 2014).

Due to the data and methodology limitations, we recommend that further research be undertaken to understand how the geographies of implementation of NBS relate to differences in urban QoL at city and neighbourhood scales. This work should examine the relationship between the processes that lead to the implementation of NBS to ask how we can evolve the framework for NBS to adapt to climate change and re-establish the connection between society and nature without reproducing structural inequalities. This work should also investigate how NBS may be mainstreamed to create a broader array of ecological domains and ecosystem services and how the balance between the number of services and disservices can impact improvements in biodiversity, climate change adaptation and QoL.

5 Temporal distribution of Nature-based Solutions, social and health inequalities in European cities Temporal distribution of Nature-based Solutions and Quality of Life in European cities

Abstract

Despite growing evidence of the relationship between urban green interventions, health and the unequal distribution of greenspace in areas of disadvantage, there are few studies providing substantive evidence to show how NBS mediate the upstream determinants of social vulnerability and poor quality of life that could help cities realise just transitions to sustainability. Consequently, critiques are emerging that suggest NBS are dominated by normative assumptions that suggest 'different' societal challenges to be addressed by NBS are mutually compatible and hegemonic narratives that neoliberalise nature.

Other scholars allege that the conceptualisation of NBS has evolved away from these framings to one that places the benefits for people and nature on an equal footing. However, recent scholarship suggests that win-win narratives and power imbalances across cities-citizen interactions continue to blight the potential of NBS reinforcing the 'externalisation of nature for society' paradigms. In this paper, we use data published in the Urban Audit and Urban Nature Atlas (which retrospectively classified 1000 urban green interventions as NBS that were deployed between 1990 and 2017) to examine how the interrelationship between governance and participation and in turn, how these relate to different social and economic conditions that influence quality of life.

Keywords: Nature-based solutions, Environmental Injustice, Governance, Participation, Quality of life, Socio-economic Position.

5.1 Introduction

Nature-based solutions (NBS) aim to harness the power of urban nature to protect, manage and restore natural or modified ecosystems and create bundles of interconnected ecosystems services (Cohen-Shacham et al. 2016; Frantzeskaki, 2019; Raymond et al. 2017) to tackle deeply complex and often highly interrelated challenges. However, lack of clarity and evidence (Van de Berg et al. 2015) about the interrelationships between highly complex phenomena or compatibility of different solutions (Pineda-Pinto et al. 2020; Calderon et al. 2021; Cousins, 2021) has led to criticism that NBS are underpinned by normative assumptions and hegemonic narratives that neoliberalise nature ((Tzoulos et al. 2021; Kotsila et al. 2020). Scholars (Sekulova et al. 2020; Woronieski et al. 2020; Welden et al. 2021) highlight that the interplay between different actors, normative frames of reference and the multifaceted nature of NBS implementation processes can not only be used by municipalities to side-step issues such as inequality but also continue to reinforce the dominated by human-nature dichotomy. Consequently, scholars (Cousins 2020; Welden et al. 2021) argue that the persistent use of normative expressions and hegemonic goals continue to hinder the just implementation of NBS in cities by disempowering citizens and creating issues of environmental justice. In contrast, Mace (2014), Cohen-Shacham et al. (2019) and Folke et al. (2021) argue that nature conservation paradigms that underpin concepts like NBS have evolved from a position where hegemonic goals persist that encourage the externalisation of nature to a position where the benefits of these interventions are intended to be divided equally among people and nature. Anguelovski et al. (2020) highlight that there is a lack of studies, including quantitative studies that unpack how the practices of NBS have changed and evolve over time to add empirical insight into these debates. To address this gap, this study adopts an environmental justice lens (Hollifield et al. 2018) and applies statistical relational methods (Faulconbridge, 2017; Boggs and Rantisi, 2003) to unpack the interplay between different types of governance, participation and citizen involvement, how the patterns that emerge have evolved over time and relate to different social and economic conditions that influence quality of life (QoL).

5.2 Understanding the relationship between NBS, Quality of Life and Environmental Justice

5.2.1 Environmental justice and environmental inequality

While NBS are typically framed as a public good, research suggests that some groups who live in communities being rejuvenated by NBS are often excluded and made invisible by actors responsible for deploying these solutions (Anguelovski et al. 2018; Cole et al. 2017). Consequently, Toxopeus, et al. (2020) argue that socio-political processes at play among actors involved in the governance and management of NBS may inadvertently create issues of environmental injustice. Scholsberg (2007) and Walker (2012) argue that the principles of environmental justice are pluralistic in nature and deeply rooted in the economic structure of society. Thus, this paper adopts the definition of environmental justice developed by Hollifield et al. (2018) which defines environmental justice as a multidimensional concept that encompasses distribution, procedural participatory, justice as recognition and justice as capabilities as well as the interactions between each of these dimensions.

Drawing on Rawls (1971) and Scholsberg (2007), distributive justice relates to the equitable distribution of benefits of NBS (resources including natural resources, opportunities and freedoms) and the extent to which their benefits can be accessed by society. Fraser and Honneth (2003) argue that the distributive justice paradigm also includes the underlying processes that construct and influence distribution such as equity, recognition, and participation. Procedural justice is concerned with the extent to which decision-making processes adopted in the governance and management of NBS are fair and equitable. Recognitional justice refers to the recognition or respect given to different actors or societal groups during decision-making, but also considers the processes that construct that distribution such as the ability of society to participate (Scholsberg, 2007; Fraser and Honneth, 2003).

5.2.2 Governance, modes of participation and citizen involvement in NBS

Sekulova and Anguelovski (2017) argue that the governance of NBS involves complex phenomena that involve different social and political actors, premises, and visions. These phenomena encompass the relationship between government and society that embodies both formal and informal institutions, rules, mechanisms, and processes of collective decision-making (Buizer et al. 2015; Chaffin et al. 2016). The conditions enable actors to influence and

co-ordinate their independent needs of interests and interactions with the environment operate at different scales. Still, Topoxpeus et al. (2020) argue just NBS require an emphasis on community-based decision-making across policy and practice to deliver just outcomes for both society and the environment. In this study, we adopt the typology developed by Sekulova and Anguelovski (2017) and Almassy et al. (2017) that categorised the governance arrangements of NBS into three public or state-led forms of governance, multi-stakeholder forms of governance such as co-governance or hybrid governance, or governance led by non-governmental actors. Government-led refers to those conditions where the government or the state has control over policy development and its implementation. Co- or hybrid governance (Toxopeus et al. 2020) relates to collaborative forms of governance that may involve multiple actors including citizens, the state, business, and civil society (Kabisch et al. 2016). Tozopeus argues that hybrid governance overlaps with concepts such as polycentric (Ostrom, 2010), mosaic governance (Buijus et al. 2019) or co-creation processes (Frantzeskaki, 2016, 2019). In contrast, NBS that are governed or managed by non-governmental organisations that may include the private sector, business, citizens, NGOs and public or private institutions are referred to as 'governance led by non-governmental actors' by Naturvation.

To unpack the interrelationship between governance, participation and QoL, we draw also on the concept of citizen participation. Participation in governance processes is not only important for increasing resilience to climate adaptation and providing a sense of project ownership, but it also allows local and indigenous knowledge to be built into the design, planning, management and implementation of NBS. However, the term 'citizen' is a 'heterogenous and contested category' (Kiss et al. 2021, pp. 248), it is understood as a 'continuum of interaction' between different political institutions, a diverse array of governmental and non-governmental actors and citizens (Kiss et al. 2021). To unpack the interplay between governance and different types of participatory approaches adopted by NBS, we draw on the seminal work of Arnstein (1969) that provides a continuum divided into 'eight' categories of participation that range from non-participation to complete delegation and empowerment of stakeholders or citizens in participatory processes. In the context of Naturvation, participatory methods or community involvement are terms adopted by project to describe the type of participatory

method embedded within governance or the management of NBS and different approaches that were used to involve citizens in the evaluation or assessment of the NBS.

5.3 Quality of Life and Socio-economic position

Nature plays a pivotal role in the QoL recognised in the Global Standard for NBS (ICUN, 2020), describing our relationship with nature as fundamental to human existence and essential for 'good life quality'. QoL is a contested, multifaceted construct and interdisciplinary field of study with no agreed definition that is more akin to a conceptual framework than a theory (Murgas, 2018; Pacione, 2003). In this study, we draw on the definition developed by Veenhoven (2014) that argues QoL is a networked concept with dynamic interactions between objective (such as income), subjective life conditions (family structure, social networks) and the degree of congruence or dissonance that people have with their everyday living environment, and the influence of socio-political factors, equitability of access of resources and principles of justice. To represent QoL in this study, we use different indicators of Socio-Economic Position (SEP) published in the Urban Audit that closely relate to QoL (Rubin et al. 2014; Garlobardes et al. 2007).

SEP is an aggregate concept with no single preferred indicator that is indicative of people's position within the social hierarchy of society, their likelihood of being exposed to harmful effects of urbanisation or climate change, or capability to resources that might mediate these effects or enhance health (Lynch and Kaplan, 2000; Marmot, 2010, Garlobardes et al. 2007). This definition describes material or social resources and assets (such as income or education) and prestige-based measures related to social class position (Krieger et al. 1997). Factors such as resource ownership and control, but cultural, behavioural factors and power differentials may also be influential (Salmond et al. 2007).

Salmond et al. (2007) argues that combining different theoretical approaches to measuring SEP creates a stronger evidence base of socio-economic adversity in cities than using individual measures of SEP. Thus, we create an area-measure of SEP, based on indicators for education, occupation, income, and risk of poverty published by the UA to represent QoL (see table 1).

Education captures opportunities for knowledge-related assets; lack of formal qualifications is an essential feature of deprivation and driver in inter-generational socio-economic mobility. It can also be used as a proxy measure of income since it is a strong determinant of future employment and income (Galobardes et al. 2007; Lynch and Kaplan, 2000). In contrast, occupation can reflect a person's place in society related to their social standing, income and intellect, but patterns of employment have changed markedly across different economies altering the pattern of distribution of occupation types and unemployment levels across the economically-active population. However, scholars (Purcell, 2018; Galobardes et al. 2004, 2007) highlight that these schemes have not been updated to reflect these patterns. For example, Purcell (2018) suggests that many schemas do not reflect the emergence of informal economies, unpaid domestic and caring roles, and other forms of unpaid employment. Thus, indicators for income represent access to material resources (such as food or housing) and at risk of poverty since some indicators of occupation exclude those social groups at risk of the consequences of social stratification (Salmond et al. 2006).

Indicators of Social Economic Position	**Source**
Education	Galobardes et al. 2007; Lynch and Kaplan, 2000
EU_SILC (Statistics on Income and Living Conditions) Occupation indicator	Purcell, 2018; Galobardes et al. 2004, 2007;
Average or median income	Krieger et al. 1997; Salmond et al. 2007
Poverty due to social transfers or low working hours	Purcell, 2018; Salmond et al. 2007

Table 5-1 Summary of the theoretical basis of the socio-economic position indices

5.4 Methodology

5.4.1 Data sources and approach

5.4.1.1 Urban Nature Atlas

The Urban Nature Atlas (UNA) database and online mapping tool includes quantitative and qualitative data describing the type, form, function, and distribution of 1000 NBS across European cities. Master's students from different European institutions completed discourse analysis of secondary documents (including project reports, information published online, etc.) for up to ten NBS in each European city between January and September 2017. Data collected included binary categorical variables that described the goals of the intervention, its key characteristics such as the ecological domain, scale, and primary beneficiaries, but also the forms of governance, innovation and evaluation and learning being adopted by each NBS alongside qualitative commentaries for indicators such as the goals of the intervention or types of stakeholders involved in the governance of NBS. Table 2 summarises the variables published by the UNA that were used in the analysis. In addition, textual commentaries accompanied some of the binary variables (to add context or further explanation regarding the variable in question). Using autonomous counting (following Hannah, 2011), qualitative data were transformed by Naturvation to create binary categorical variables representative of urban

Group variable	Sub categories
Governance arrangements that characterise the power distribution of an NBS	Government-led, hybrid or mixed governance, or governance led by non-governmental actors
Stakeholders that lead co-governance or non-governmental actors that lead the governance of NBS	Public sector, non-governmental organisation or civic society, private sector, corporate or business, research institutions, citizens or community groups, or, coalition of different actors

Participatory methods or forms of community involvement	Subcategories of participatory methods as defined by Naturvation: Co-creation, co-development or co-planning; crowdsourcing or crowd-funding; participatory budgeting; task force or citizen jury's; information dissemination; consultation; joint implementation; joint or co-management; citizen oversight; citizen science; citizen monitoring or review.
Modes of citizen involvement	Modes of citizen involvement as defined by Naturvation: Focus group; interviews; questionnaire; online forums; submission of monitoring data by citizens.
Primary beneficiaries	National-level government (including public agencies); local government/municipality; public sector institution (such as a school or hospital); non-government organisation or civil society (including a not-for profit organization, international organizations or the private sector); private sector, or corporate company; researchers/university; citizens or community groups disadvantaged groups (e.g. older or disabled people, families with small children).
Supplementary Variables	
Ecological domains	Categories of different types of NBS and their subcategories that consist of parks, blue spaces, grey infrastructure connected to greenspace, green areas for water management (such as SUDS), allotments and community gardens and external green building (such as green roofs).

Ecosystem services	Four types of ecosystem service with each sub-category including provisional, regulatory, habitat supporting or cultural ecosystem services.
Key Actors	Naturvation categorised key actors into: multilateral organizations, EU bodies, national or regional or local government, public sector institutions, non-governmental organisation/civil society, business associations, private sector/corporate/company, or private foundation, transnational network, researchers/universities, citizens or community groups.

Table 5-2 Summary of the indicators published in the UNA that formed the basis of the MFA. (Note: Indicators that were used as supplementary indicators to aid contextual understanding but were not used to construct the principal components are listed as supplementary variables) (Source: adapted from Almassy et al. 2017)

conditions of NBS. (Almassy et al. 2017). While Hannah (2011) is critical of the use of count frequencies arguing that it limits the ability to generate insights from qualitative research processes other scholars (Bourdieu, 1983; Lebaron 2018) argue that independent analysis of quantitative and qualitative data can conceal complex relationships within systems. Monrouxe and Rees (2019) and Neale et al. (2014) suggest that quantification of qualitative data allows us to reveal complex relationships within systems and enhances the transparency of analysis.

5.4.1.2 Urban Audit

To create a composite indicator representative of SEP, the study conducted a principal component analysis of secondary data published in the Urban Audit (UA), one of the only pan-European datasets that consist of QoL indicators for cities (Eurostat, 2017). The UA includes demographic, social, economic, environmental, training/education, and (for a limited number) health indicators for selected European cities. Many of the indicators collected by the UA play a central role in capturing the everyday realities of social inequality (Nolan & Whelan, 2011) and can help illuminate how different urban conditions that influence the QoL relate to different

practices of governance and participation that have influenced the implementation of NBS. Table 2 (section 2.2) summarises the indicators published by the UA that were used to create the SEP indices to represent QoL.

5.5 Multiple Factor Analysis

This study uses relational quantitative methods to unpack how different attributes of NBS, focusing on their governance typologies and different modes of participation or citizen involvement interact within complex systems to influence QoL. Scholars (Faulconbridge ,2017; Le Roux et al. 2019; Lebaron, 2019; Lefevre et al. 2014) argue large, structured datasets (such as the UNA) require systematic analysis that takes a heuristic approach to unravel their complex patterns. This approach allows the interplay between inter-relationships within structured data to be unpacked both in terms of how the pattern between governance, citizen participation and QoL are clustered, but also how different cities implementing NBS may be grouped. To achieve this, we apply a geometric data analysis technique known as Multifactor Analysis using the FactomineR package in R software and visualise the results in the FactoExtra package (Le Josse & Hudson, 2008; R Core Team, 2000). MFA is a geometric data analysis (GDA) technique that represents structured datasets as clouds of points in a multidimensional space (Le Roux et al. 2019). Unlike other similar techniques (such as PCA) MFA can simultaneously analyse the strength of the relationships between different observations described by sets of variables (or groups) as well as relationships between groups and different subsets of variables (for example, relationships between different categories of grouped variables and their subset of indicators listed in table 1) (Ecofier & Pages, 1994).

Action on what researchers, policymakers and practitioners refer to as NBS has slowly evolved overtime and appeared under many guises (such as natural solutions and ecosystem adaptation) (see Nesshover et al. 2017); a formal name by the World Bank in the late 2000's following introduction of the ecosystems services framework (Mittermeier et al. 2008). Around this time, scholars argue paradigm shifts were also occurring in nature conservation (Mace, 2014); people were not just passive beneficiaries of efforts to external nature but deeply intertwined, with interrelationships co-evolving across time and space, influencing the interface between

preconditions for good QoL (Folke et al. 2021; Reyers et al. 2018).) Thus, to trace how the network of interrelations between different types of governance, participation and QoL over time, we disaggregate the UNA dataset into two matrices for analysis selecting the timing of the introduction of the definition of NBS as the dividing point. An MFA analysis is completed on each matrices analysis based on the attributes of NBS that relate to governance, citizen participation, primary beneficiaries and QoL. While different types of ecological domains and key actors involved were used as supplementary variables to aid contextual understanding; these variables were not used to construct each of the dimensions or principal components.

5.6 Hierarchical k-means clustering on MFA

To identify groupings of different factors that influence the interrelationship between governance, type of participation or community involvement and quality of life, hierarchical cluster analysis was applied to the results of the MFA. Clustering is a method of machine learning that is used to identify groupings, or clusters, within data based upon similarities or differences. Hennig et al. (2015) define clustering as identifying groupings in data based on partitions within the data that are 'hard' or categorical or 'soft' based on the degree of membership within each group or cluster. The authors describe these types of clustering as flat, but if each group can be partitioned into subgroups, this is referred to as hierarchical clustering. Using the FactomineR package we conducted hierarchical clustering using Ward's (1963) criterion on the first five factors selected for analysis from the MFA. Similarly to multidimensional ordinal methods such as MFA, hierarchical clustering is based on multidimensional variance as well as the analysis of principal components (Husson et al. 2010). Hierarchical K-means cluster analysis that partitions the data into a set of groups or classes (i.e. *k* clusters) based on their similarity.

5.7 Results

This section presents the analysis of how the complex interplay between different types of governance and participatory methods used by NBS and QoL evolves over time. Multiple factor analysis of the interplay between governance, participation and QoL.

5.7.1 Pattern of clustering of interaction between governance, participation or citizen involvement, and quality of life from 1990 to 2009

Figure 1 shows the factor map from the Hierarchical Cluster Analysis applied to the Multiple Factor Analysis of different types of governance, participation and citizen involvement, the principal beneficiaries of NBS, and QoL in cities. The factor map shows that prior to the introduction of the formal definition of NBS and the Millennium Assessment Framework for Ecosystem Services, different types of governance and participatory methods adopted by NBS where divided into distinct three clusters. These results suggest that throughout the 1990s and early 2000s NBS often failed to engage or empower communities in the governance or management of NBS leading to participatory or recognition injustice. Sections 4.1.1 to 4.1.3 present the results of analysis of the v-Test statistics which v-test statistics indicate if the clusters mean is lower or greater than the overall mean of the cluster; only v-test statistics higher than +/- 1.96 correspond to a p-value less than 0.05 (Le Josse & Hudson, 2008; Le Roux et al. 2019). Figure 2 shows the distribution of v-test statistics for different forms of governance and participation that are significantly related to the first cluster.)

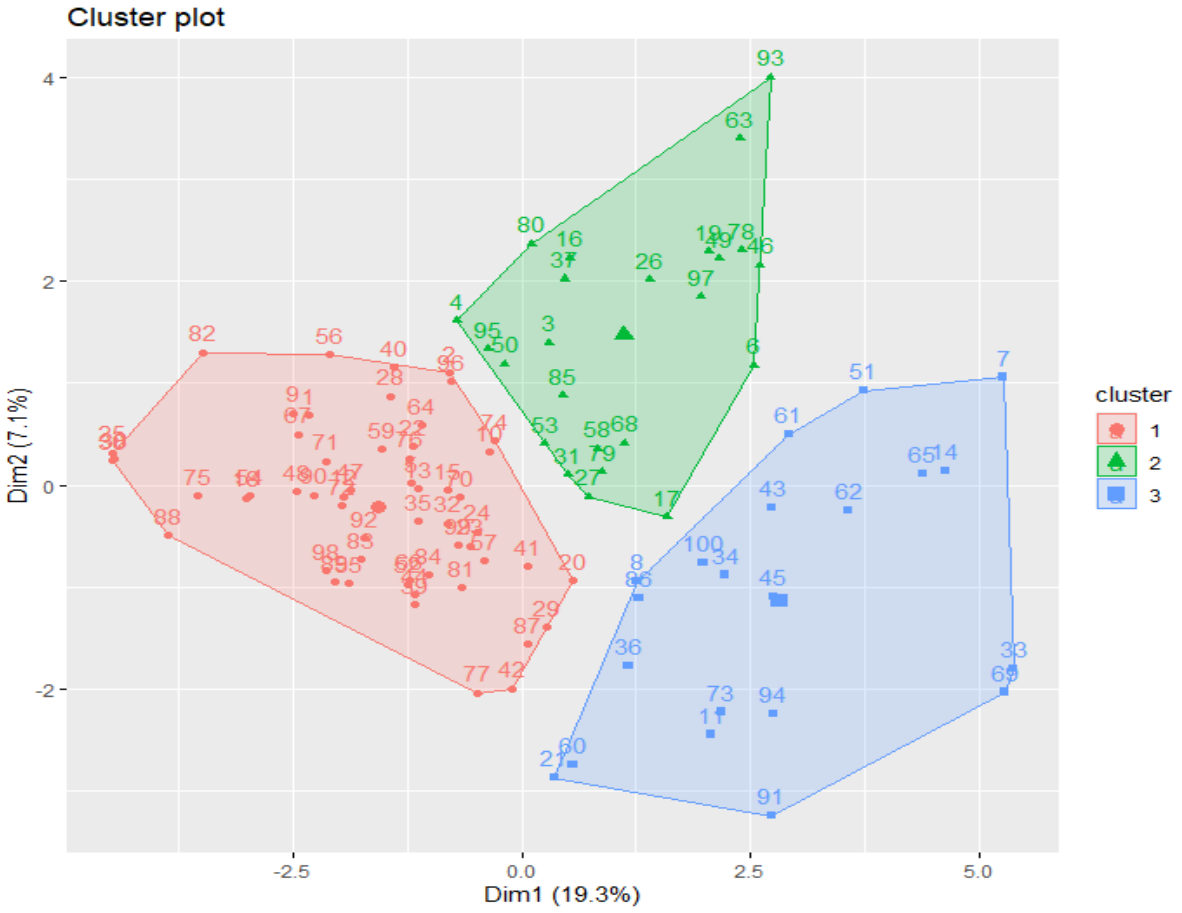


Figure 5-1 Factor Map showing distribution of clusters of NBS implemented between 1990 and 2009

5.7.2 NBS water management lack opportunities to empower citizens as central actors – Cluster 1

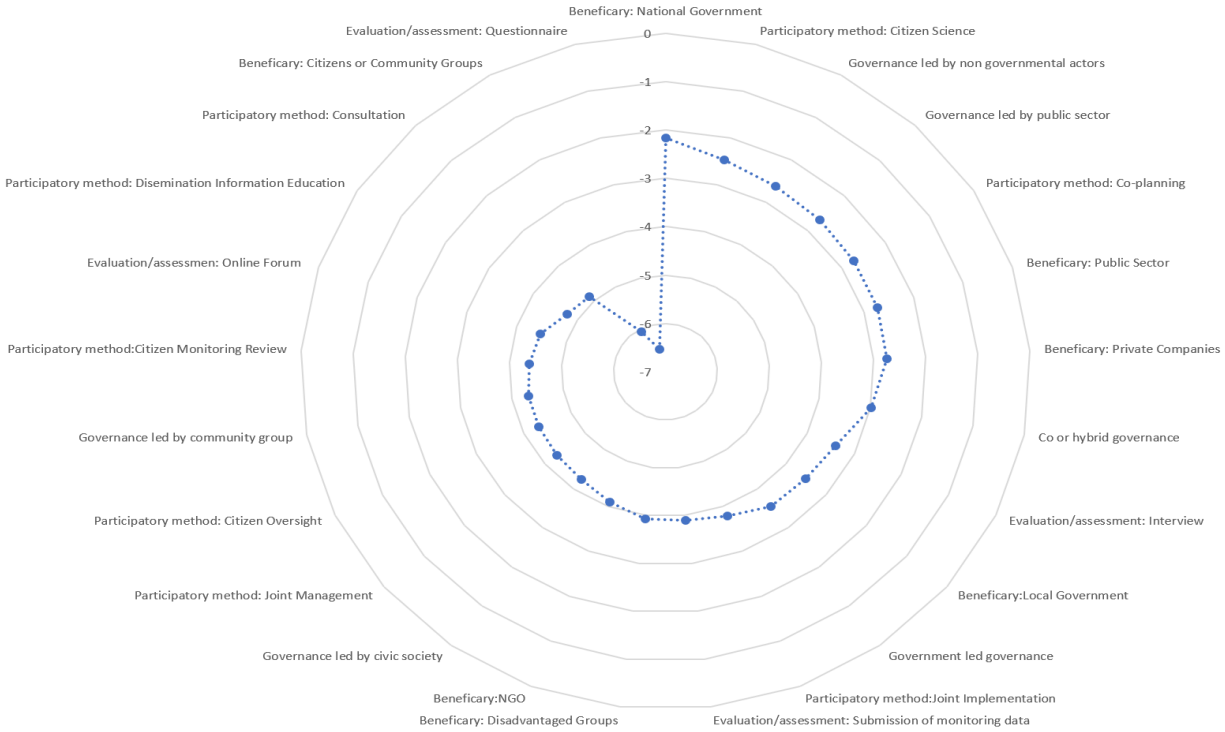


Figure 5-2 Spider graph showing distribution of V-test scores for cluster 1 of NBS implemented between 1990 and 2009 (significant p value 0.05)

Cluster 1 represents NBS deployed by just over 50% of cities included in the UNA when Mace (2014) suggest nature conservation paradigms that underpinned NBS were dominated by views that nature could be exploited or managed for the benefit of society. These results suggest that through the 1990s and 2000s a mixture of different types of governance were adopted. Figure 2 shows the V-test statistics for each type of governance and participation together with the primary beneficiaries of NBS that were significantly related to cluster 1. They suggest that while these NBS adopted different institutional practices, citizen participation was often limited to more tokenistic forms of engagement suggesting these NBS were primarily for the benefit of powerful private sector or governmental actors. These actors may have had play a role in influencing the prioritisation of the type of ecological domains that are deployed by cities. These trends are also reflected in the pattern of distribution of cities implementing NBS at this time to revitalise decaying urban infrastructure under the guise of climate urbanism (Cooper et al. submitted).

Figure 2 suggests that conditions that enable power sharing (such as citizen management) are lacking with participation limited to more tokenistic methods (Arnstein, 1969) such as co-planning, consultation and information dissemination, or delegated power such as joint management or citizen oversight. These findings maybe explained the fact that different types of ecological domains (that could be constituted as blue-green infrastructure) are being implemented to address water management and climate challenges for the benefit of national government and private companies. Consequently, this leads to missed opportunities to address urban biodiversity goals and justly distribute the benefits of NBS. We suggest that the actors designing and deploying these solutions may 'assume' the delivery of benefits rather than realise them due to a lack of awareness of the synergistic relationship between different challenges that NBS seek to address. Consequently, the lack of empowerment of citizens as central actors or inclusion of these groups in the design and planning phase may have led to recognition or participatory injustice and missed opportunities to create just and design transformative NBS.

5.7.3 Recognition injustice cluster – cluster 2

Unlike the first cluster, the NBS that characterise cluster 2 is associated with a much smaller group of indicators. Our analysis suggests that the second cluster exemplifies 24% of cities implementing NBS between 1990s and the late 2000s. These NBS are governed by the state or by non-governmental actors such as the public sector, civic society, or community groups but similarly to the first cluster different forms of participation are largely limited to citizen oversight or task force involvement, co-planning, monitoring and information dissemination and unrelated to QoL. Like Kiss et al. (2021) we find that different modes are participation seem tokenistic and lack evidence of empowerment of civic society to manage and implement NBS, but really on these groups for resources to monitor and evaluate NBS. We argue that these results not only indicate participatory and recognition injustice, but suggest that the politics of recognition (Rawls, 1999) may be resulting in distributional injustice as issues of misrecognition and lack of association with QoL reinforce each other causing maldistribution of NBS.

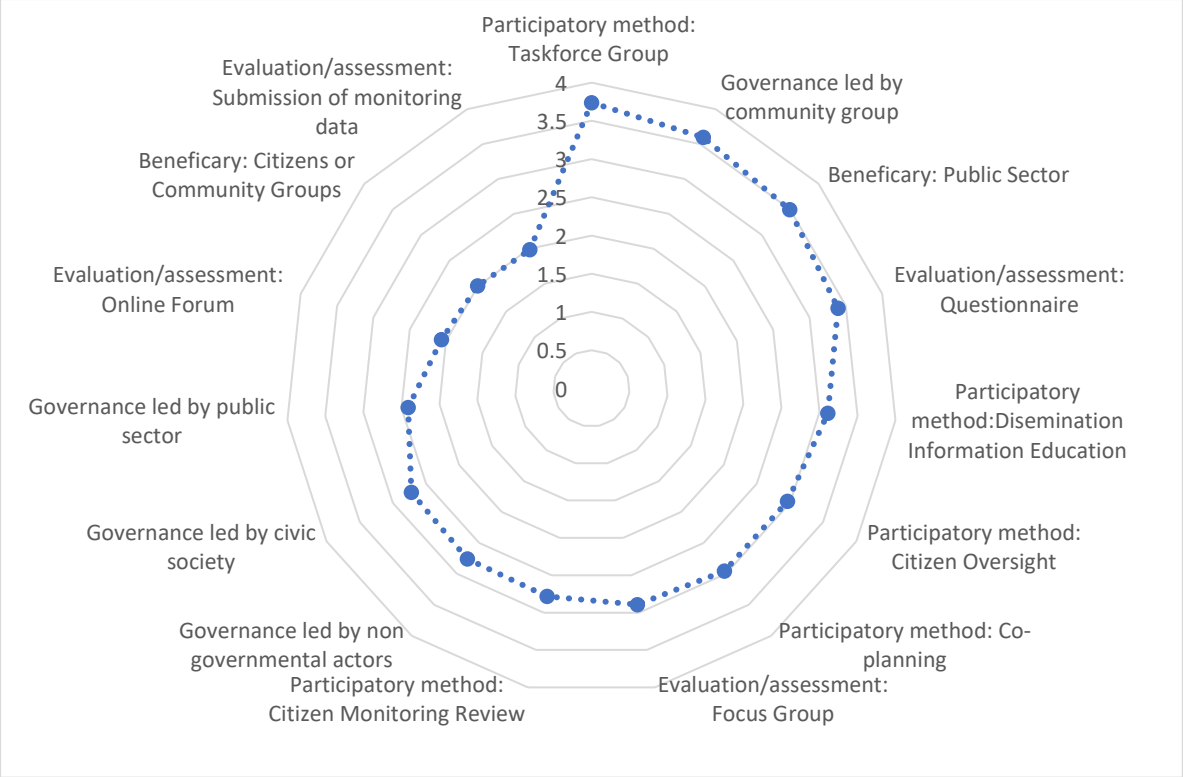


Figure 5-3 Spider graph showing distribution of V-test scores for cluster 2 of NBS implemented between 1990 and 2009 (significant p value 0.05)

5.7.4 Co-governed NBS disempower communities – cluster 3

21% of cities implementing NBS before 2010 are strongly associated with co-governance of NBS for the benefit of multiple actors including disadvantaged groups by creating opportunities for urban gardening, large urban parks, and blue-green infrastructure. These cities aspire to create multifunctional (Frantzeskaki et al. 2019) and justly distribute NBS, similarly to the previous two clusters, modes of participation are largely devoid of power sharing resulting in recognition injustice denying citizens an opportunity to influence the design, management and implementation of NBS. These findings concur with Kiss et al. (2021), Puskas et al. (2021), Wamsler et al. (2019) and Brink and Wamsler (2017) suggest current institutional arrangements that include citizen engagement are driven by strategic considerations to aid validation of decision-making or manage (or prevent) conflicts and hence lack equity considerations. Our results also suggest that the involvement of citizens with data collection through online forums and focus groups is somewhat tokenistic and unjust, denying

citizens and disadvantaged groups the opportunity to develop capabilities that could help them transform to sustainability.

5.7.5 Pattern of clustering of the interactions between governance, participation, and citizen engagement from 2010 to 2017

Figure 5-4 Factor Map showing distribution of clusters of NBS implemented between 2010 and 2017

5.7.6 Coalitions of actors govern multifunctional NBS – cluster 1

After 2010, NBSs that are governed more collaboratively begin to emerge adopting a broader array of participation methods that are divided into four typologies some of which overlap as shown in figure 4. The first cluster (shown in red) accounts for just over 50% of cities with

examples of NBS published in the UNA. Our analysis suggests that a broad array of different participatory methods is significantly related to this cluster that devolves some power for decision-making and management of NBS to citizens, but these are largely limited to co-planning, consultation and involvement in task force groups. Furthermore, disadvantaged groups as beneficiaries of NBS and none of the QoL indicators that were included in the analysis are significantly related to this cluster casting doubt over the extent to which these NBS are distributionally just. Lack of recognition of the role of citizens in participatory processes not only leads to misrecognition but also denies these groups to develop capabilities that would allow them to improve their QoL and well-being.

Kiss et al. (2021) suggest that these processes are used by powerful actors to legitimize decisions by the municipality and often lack transparency leading to distrust and non-cooperation (Woroniecki et al. 2019). While we are unable to collaborate on these findings in this study, the range of beneficiaries that are significantly associated with this cluster and the lack of evidence of citizen management of these NBS could suggest that evidence of unequal power-sharing leads to recognition of injustice. However, further analysis of the cases is required to verify these claims.

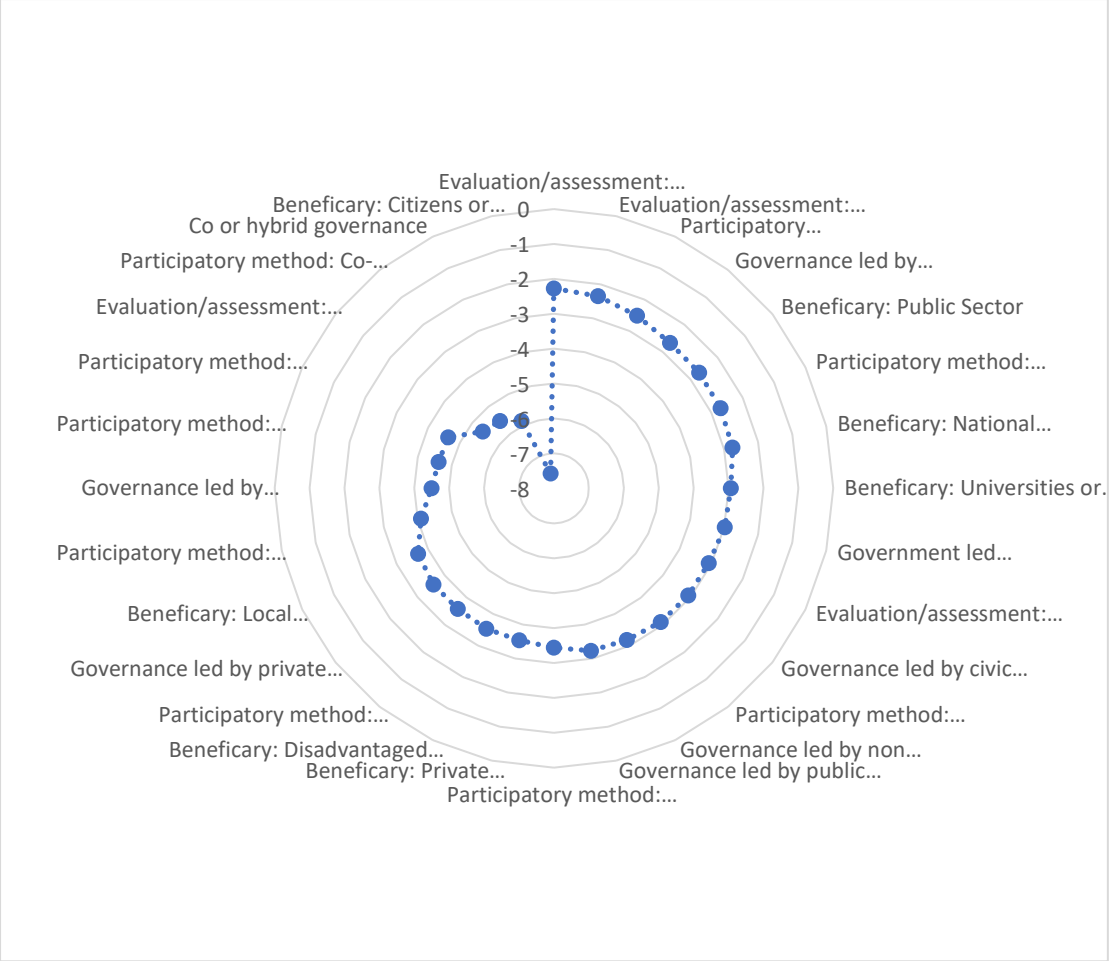


Figure 5-5 Spider graph showing distribution of V-test scores for cluster 1 of NBS implemented between 2010 and 2017 (significant p value 0.05)

5.7.7 Emerging NBS for disadvantaged citizens risk becoming unjust – cluster 2

The second is primarily governed by community-led or the state with different forms of participation limited to crowd sourcing, co-planning, and consultation. This cluster of NBS represents 21% of cities that are beginning to deploy NBS to help revitalise urban areas through the creation of urban greenspace connected to grey infrastructure to provide opportunities for recreation, mental and physical well-being, aesthetic appreciation, and noise reduction for the benefit of disadvantaged groups.

A closer examination of qualitative commentaries that describe the goals of these NBS suggests that cities are deploying NBS to help revive decaying urban areas even though QoL is not

significantly associated with this cluster. While a lack of evidence of a relationship between QoL and the interplay between participation and governance in this cluster may reflect the stage of implementation of these NBS, it could also use of normative framings for NBS leading to missed opportunities to design interventions providing resources to help improve QoL and mediate ill-health caused by climate change and urbanisation.

5.7.8 NBS governed by private companies led to environmental justice – cluster 3

This group of NBS are governed by civic society or private companies to create opportunities for urban food growing opportunities or blue-green infrastructure. Analysis suggests that these interventions are primarily for the benefit of the national government, private companies, and research institutions (v-test 3.34 & 2.84) and there is a lack of evidence of a relationship with factors that relate to QoL. Different methods of citizen engagement are limited to co-planning and data collection for the evaluation and assessment of NBS through interviews and questionnaires. This appears somewhat tokenistic to tap into local knowledge to facilitate data collection rather than educate urban inhabitants to facilitate transition to sustainability. Hence, while these NBS aim to create opportunities for recreation and to improve health and well-being, we suggest that the private actors that govern these solutions miss opportunities to adopt more inclusive governance processes that could help empower citizens and disadvantaged groups to develop abilities and capabilities that could help them access or use these resources leading to procedural and recognition injustice.

5.7.9 Waterfront urban redevelopment led by the municipality – cluster 4

The final cluster is most closely associated with QoL and joint implementation of NBS that are governed by civic society NBS for the benefit of private companies, research institutions or citizens including disadvantaged groups through the creation of blue-green infrastructure to regulate flooding, but also create habitats for species and maintain genetic diversity. Our analysis suggests that these NBS adopt a broad array of participatory methods to engage communities in the planning, management, and implementation of NBS, but while these interventions are for the benefit of disadvantaged groups it is not clear to what extent this group are deeply engaged with these processes.

5.8 Discussion

In this paper, we explore how the pattern of interaction between governance, citizen participation, beneficiaries of NBS and QoL evolve over time, from the early 1990s when NBS first began to emerge to the late 2017s when operational guidance for implementation of NBS was published by the ICUN and European Commission. In doing so, this study unpacks the interplay between governance, citizen participation and QoL, how this pattern evolves through time and the implications for environmental justice.

Our results suggest that different patterns in the interaction between governance citizen participation and beneficiaries of NBS are rarely related to QoL both throughout the 1990s and 2000s, but also in more recent times suggesting the implementation of NBS are largely being framed to reinforce the dichotomous relationship with nature hindering the transformative potential of NBS in cities. Only two clusters of city-citizen interactions identified by the cluster analysis are related to QoL. Similarly to Welden et al. (2020; 2021), Woronieski et al. (2020) and Wamsler et al.(2019), our findings show that actors and stakeholders actors involved in the implementation of NBS continue to frame and design solutions based on their own needs and agendas leading to the uneven distribution of benefits among nature and people is creating issues of ecological and environmental injustice. Despite claims that paradigms that underpin NBS have evolved to centre the benefits on nature and people (Mace, 2014; Cohen-Shacham et al. 2019; Folke et al. 2021) while also advocating fair and equitable distribution and broad participation (Cohen-Shacham et al. 2016), we argue that lack of knowledge and understanding of the concept (Howe et al. 2014), uneven power relations embedded in governance processes (Berbes-Blazquez et al. 2016) coupled with an inattention to historical and structural injustices (Nuti, 2019) has led to the continued entanglement of NBS with neoliberal practices that are reproducing or exacerbating inequalities.

5.9 NBS operate in a 'veil of ignorance' 1990s and 2000s leading to recognition and participatory injustice.

Over 60% of cities (cluster 1 and 2) implementing urban green projects retrospectively classified as NBS deployed by post-industrial cities to transform decaying urban infrastructure

under the guise of climate urbanism (Rosol et al. 2017; Long & Rice, 2019) and new city-making paradigms (Marshall, 2004; Schuetze & Chelleri, 2016). Across each of the clusters, institutional arrangements are often governed by non-governmental actors (such as private companies) or collaborative arrangement involving both private and state actors. Different forms of participation largely focus on tokenistic forms of engagement that lead to the disempowerment of communities leading to recognition and participatory injustice. Furthermore, disadvantaged groups are also largely excluded. These findings suggest that actors implementing these solutions operate within a 'veil of ignorance' (Rawls, 1999) unaware of opportunities being missed to improve QoL of citizens and help cities make just transitions to sustainability. Wamsler (et al. 2019) and Brink and Wamsler (2017) argue that institutional arrangements are often driven by strategic and rarely equity considerations leading to what Marion Young (2011) refers to as the exclusionary 'politics of difference'. This not only leads to the domination and oppression of marginalised groups that could benefit from NBS, but also denies urban inhabitants the opportunity to develop and exercise their capability to access resources that could help them transition to sustainability and improve their QoL.

In this study, we found that the pattern of interplay between governance, citizen participation and those receiving the benefits of NBS was only significantly related to QoL in two clusters. These results concur with other studies (e.g., Long and Rice, 2019; Dangelico and Pontradolfo 2015) that suggest urban green interventions implemented by actors during the 1990s and 2000s often reinforced the human-nature dichotomy leading to the maldistribution of environmental goods and increasing the vulnerability of those at risk of adverse health effects of urbanisation and climate.

Despite poor equity considerations, governance, and citizen participation through the involvement of citizens in monitoring and review play an important role in the first cluster. Scholars argue (Cardenas et al. 2021; Schuttler et al. 2018) citizen participation in the design, management and monitoring of NBS through citizen science can play an important role in transforming societal attitudes to sustainability, but can also enhance social learning, civic engagement improve health and well-being (Ceccaroni et al. 2021). However, our findings suggest the use of citizen science appears to be functional for data collection rather than

transformative suggesting that private actors may deploy citizen science to improve their marketability or diffuse concerns or opposition urban development or environmental impacts. Previous research also suggests that participation in citizen science projects tend not to be representative of communities often dominated by white, highly educated ethic groups (Burgess et al. 2017; Blake et al. 2020; Pateman et al. 2021). However, based on data available it is not possible to clarify if the citizen science deployed by private actors was designed in collaboration with them to facilitate data collection or analysis, or co-created by them to actively encourage agency with NBS (King et al. 2019; Rosas et al. 2021). Hence, further research is needed to examine how socio-political processes associated with the deployment of citizen science in NBS influence or hinder just transformations and in turn, create issues of participatory and/or recognition injustice.

In the second cluster, interaction between governance, citizen participation and beneficiaries of NBS are influenced by fiscal drivers to secure foreign investment to regenerate post-industrial or shrinking cities to rebrand and transform areas perceived as 'wastelands' (Kronenberg, 2015; Hasse, et al. 2019) into large urban parks. Lack of evidence of a relationship with QoL and misrecognition of citizens suggests these NBS externalise nature for society leading to the maldistribution of benefits and deny citizens the opportunity to develop capability to access these resources through inclusive institutional and participatory processes. The lack of participatory parity in this cluster (Fraser & Honneth, 2003) highlights the importance of not only educating different groups of actors implementing NBS about the role of NBS and how they should be framed to avoid privileging hegemonic narratives of political elites, but also the importance of recognising citizens, disadvantaged and marginalised groups in the early phases of NBS from pre-planning, grant application through to implementation to create more just cities (Torres et al. *submitted*).

The third cluster of NBS is associated with community-led governance of allotments, urban parks or blue-green infrastructure that aim to benefit people and nature through the creation of food growing opportunities for disadvantaged groups, climate and carbon regulation and habitats for species. These NBS adopt an array of participatory methods to foster inclusivity including citizen management and science. However, while this cluster of NBS claims to

benefit disadvantaged groups, they are not related to different factors that influence social vulnerability, urban deprivation, or poor health. Certoma and Tornaghi (2019) and Crossan et al. (2016) suggest that while these types of NBS can progress forms of political practice that help to alleviate food insecurity and social connectedness. However, they can also be sites where class-produced natures (Domene and Sauri, 2007) can emerge mediated by the cultural elite with higher levels of educational attainment and knowledge of nature (Exner and Schutzenberger, 2018). We suggest cultural capital may play a role in influencing stewardship of urban biodiversity goals and the extent of participatory democracy in urban greening projects such as NBS. However, further research is needed to explore the relationship between cultural capital on governance, participation, and citizen involvement across different types of NBS, particularly urban gardening and in turn, the influence on distributive, participatory and recognition injustice.

5.9.1 Collaborative NBS emerge but participatory parity hinders just transformations in cities

Following 2010 the pattern of interaction between different actors involved in the governance and management of NBS became more collaborative in nature with increasing involvement from citizens in the management or implementation of these interventions or democratic processes that facilitate the collection of monitoring data and analysis. However, our findings suggest that NBS rarely devolve governance or management solely to citizens suggesting these solutions may be underpinned by framings that dichotomise nature that prioritises urban green agendas of private and state actors. Consequently, interactions between governance and citizen participation remain largely inattentive to the 'politics of redistribution and recognition' (Honneth and Fraser, 2003), but also deny citizens, particularly vulnerable groups to develop capabilities that could help to alleviate the upstream determinants of poor health and improve QoL.

After 2010, over 50% of cities deploy NBS that are characterised by coalitions of private and public sector actors to co-create multifunctional blue-green infrastructure that involve citizens in the oversight and management of NBS. This evidence suggests cities are beginning to transition to more just governance and participatory arrangement. In another study, Toxopeus

et al. (2020) suggest hybrid governance strengthens justice outcomes of NBS by explicitly including citizen involvement and participatory governance. However, further exploration of the interplay between governance, participation and QoL suggests lack of participatory parity blights the potential of NBS to make just transitions to sustainability. We suggest that the persistent enactment of human-nature dichotomic framings by private and public sector actors coupled with inattention to the relationship between governance, participation, the distribution of benefits of NBS and QoL leads to the maldistribution of environmental goods (such as ecosystems services) that could alleviate these conditions. These findings are similar to other studies (e.g. Rosol et al. 2017; Whitten, 2019; Long & Rice, 2019) that found hegemonic narratives such as the pursuit of lucrative European investment funds, rebranding of cities or implementation of austerity measures can be key drivers for the deployment of urban greening programmes.

There is also a lack of evidence that framings that underpin the deployment of NBS by the community, private company or state-led actors have evolved to equally benefit nature and society and improve QoL. In the second cluster deployed after 2010, NBS were still in its planning and design stage at the time of data collection. Driven by urban regeneration, these NBS aim to co-create ecosystems services for people through the creation of ecosystem services for recreation, and physical and mental health, but lack evidence of services being created to support urban biodiversity agendas Our analysis suggests that these NBS aim to be inclusive by involving community actors in the consultation, co-planning or crowdfunding phase of these interventions, but lack of evidence of a relationship with QoL could suggest that these interventions are not to be located where urban inhabitants lack access to greenspace causing distributional injustice and reinforce existing inequalities. In the fourth cluster, NBS are governed by the private sector, civic society or state actors but jointly implemented with the involvement of business, research institutions, local government,t or NGO's. Although institutional and management processes are led by and involve different actors, the needs of citizens seem largely unconsidered with tokenistic opportunities for stakeholder engagement offered through interviews or completion of questionnaires which could lead to issues of procedural and recognitional injustice.

5.10 Conclusions

Comparison of the patterns of clustering of different forms of governance, citizen participation, beneficiaries of NBS and QoL adopted by different actors and stakeholders implementing NBS from 1990 to the late 2000s and then from 2010 to 2017 suggests governance arrangements have become more collaborative, but remain largely unjust often disempowering citizens and denying citizens of their right to access opportunities to develop capabilities that could improve QoL and help to facilitate just transitions to sustainability. We suggest the narratives that underpin these interventions continue to reinforce the human-nature dichotomy despite claims by Mace (2014) that nature conservation paradigms that underpin NBS have evolved to equally benefit society and nature. These findings consistent with studies by Welden et al. (2020, 2021) and Woronieski et al. (2020) who suggest that narratives that dichotomise nature continue to dominate across policy, research and practice leading to environmental and ecological injustice. These narratives will continue to act as a barrier to sustainability transitions unless action is taken to redress the use of hegemonic narratives across private and public sectors and research institutions. This will be no easy task, but we suggest that a comprehensive communications campaign to educate these actors planned by state and transnational actors be developed to improve conceptual understandings of NBS and the intertwined relationship between people and urban biodiversity.

Our research also shows that interactions between governance and citizen participation are largely devoid of citizen engagement that helps to facilitate transformative change and agency with NBS. These findings concur with Wamsler et al. (2019) and Brink and Wamsler et al. (2017) that relatively few NBS involve citizens and marginalised groups leading to participatory and recognition injustice. Thus, in light of the prevalence of evidence of environmental injustice across each cluster,it is imperative that national and local policy instruments that relate to NBS ensure citizen involvement and actively discourage other dimensions of environmental justice. Policy and regulatory frameworks and financial

instruments must evolve to discourage powerful actors from adopting socially exclusive governance processes and embed just design practices in the early phases of pre-planning and co-design of NBS. Given the diverse range of different scenario's in which different aspects of environmental injustice may occur that have been highlighted in this study, we recommend further research to is undertaken to investigate to the intersectional barriers that exist between different coalitions of actors and vulnerable community actors to help us understand why these communities are excluded from governance or management of NBS and how they can become more empowered as central actors during these processes to help realise the public health benefits of these solutions.

6 A novel approach to quantitative analysis of the relationship between Nature-based Solutions and Health at the City-Scale.

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Highlights

- This paper adopts an innovative mixed-method approach to untangle the complex relationship between different types of ecological domains and their ecosystem services and health outcome indicators.
- Different ecological domains incorporated into the design of NBS could play an important role in disrupting the complex relationship between the determinants of ill health in cities.
- Exploratory analysis of the interrelationship between different ecological domains such as external green buildings, parks, blue spaces, and derelict land with wild areas suggests mortality is moderate to strongly related to these types of NBS. However, the effect size is variable across each mortality indicator.
- This study highlights the importance of a complex systems understanding of the role that different characteristics of NBS play in disrupting the determinants of poor health in cities.

Abstract

Cities are complex hybrid systems that consist of an array of socio-technical and socio-ecological processes that interact with the built environment to influence the determinants of poor health and increase the prevalence of non-communicable disease and vulnerability to Covid-19 directly or indirectly. In response to these and other urban challenges, cities are increasingly looking towards Nature-based Solutions (NBS) to help provide secondary benefits such as improved health as they deploy these solutions to tackle social, economic, or environmental problems. While there is growing evidence of the relationship between green or

blue space and health, some scholars are critical of the presentation of health as an 'added benefit' within the definition of NBS. These scholars argue that this is partly due to poor conceptualisation of the complex interrelationship between health and NBS within the operational framework but also a lack of specific studies that examine how NBS interact with complex systems to influence health across different scales. To address this gap, this chapter presents a novel mixed-method approach that integrates statistical analysis of the relationship between different characteristics of NBS and mortality indicators at a city scale with quantitative text mining approaches such as Multidimensional Scaling and Co-occurrence Network Analysis.

6.1 Introduction

Cities are complex hybrid systems (Bettencourt, 2015; Swyngedouw, 1996) consisting of technological systems and built urban infrastructure intertwined with ecological systems to create hybrid ecosystems (Grimm et al., 2016). Through a myriad of complex patterns of flows and networks of relations that embody and mediate socio-ecological and socio-technical processes, structural and functional characteristics of cities directly or indirectly influence the determinants of health. Fudge et al., (2020) suggest many urban health challenges have emerged in cities due to urban lifestyle choices, poor planning that prioritises technological and infrastructure solutions and a lack of effective management and maintenance of urban environments leading to an increased prevalence of risk factors for chronic non-communicable diseases (NCDs). World Health Organisation (WHO) (2022) suggest that NCDs (such as cardiovascular or respiratory diseases, cancer, and diabetes) contribute to over 70% of annual deaths globally influenced by poor diet, sedentary lifestyles, obesity as well as physical and mental health problems linked to violence, deprivation and unemployment. Furthermore, one-fourth of the global population is estimated to have an underlying condition related to NCDs that increases vulnerability to Covid-19.

Cities also have large inequalities in health across social groups influenced by risk factors that co-exist and interact with the complex interrelationship between urban diversity, the built environment, income inequality and the individual determinants that accumulate over a lifetime

influenced by life choices, exposure, the development of risk factors, disease incidence and progression (Friel et al., 2011; Bonner, 2017). Climate change is also beginning to amplify deaths attributable to NCDs due to synergistic effects between extreme heat, air pollution (the second leading cause of NCDs) and aeroallergens (Anenberg et al., 2020; Campbell-Lendrum et al., 2019). A recent analysis of the Global Burden of Disease also suggests risks to harmful exposures to air pollution are increasing in nations with a low to medium socio-economic index, but declining in more prosperous nations. At the same time, the pattern of high fasting plasma glucose, BMI and alcohol use associated with increased risk of NCDs is increasing across all nations differentiated by gender, ethnicity and age (Murray et al., 2020). Other scholars suggest that sex-linked physiological differences in vulnerability and exposure may also play a role in the dose-response relationship between NBS and health, but evidence is inconclusive (Stafford et al., 2005; WHO, 2014; Bird and Rieker, 2008).

In response to these challenges, the concept Nature-Based Solutions (NBS) has emerged in response to a growing need for actions that provide multifunctional solutions to different societal problems (such as urbanization and climate change) in an integrated way. Through the use and manage urban nature, scholars claim NBS can create, restore or enhance urban ecosystems by creating bundles of ecosystem services to interrupt and mediate these complex and interrelated address problems simultaneously (Nesshover et al., 2017; Raymond et al., 2017; Cohen-Shacham et al., 2016). Growing evidence suggests that green and blue space provided by NBS is not only important for healthy living but could help to mediate risks to health associated with climate change, especially in deprived communities that lack access to green space (Mitchell and Popham, 2008; Maas et al., 2009; Mitchell et al., 2015; Ward-Thompson et al., 2013; Roe et al., 2013). Research into the pathways that link NBS and health suggests these solutions can help to relieve stress, restore mental health, improve the functioning of the immune system and provide opportunities to increase social connectedness (WHO, 2017; Hartig at el., 2014; Kabisch et al., 2017; Mitchell and Popham, 2008). Scholars (Hartig at el., 2014; Markevych et al., 2017; Dalton et al., 2016) also suggest that NBS build resilience through physical activity or improved fitness, buffering against the adverse impact of air or noise pollution, urban heat island effect or flooding.

Despite growing evidence of the benefits of NBS to public health, Van den Bosch and Sang (2017) highlight that health is not central to the framing of the concept but is a 'secondary' benefit that follows the delivery of environmental, social, and economic outcomes (Cohen-Shacham et al. 2015). Dumitru et al., (2020) and Van de Berg et al., (2015) blame conceptual deficiencies on the lack of specific studies that provide causal evidence of the relationship between the role that different types of NBS and the role that they play in mediating the upstream determinants of poor health. In contrast, Rutter et al., (2017) Alberti et al., (2018) and Curtis (2010) argue the lack of evidence of impact is a consequence of the failure to conceptualise how multiple agents of NBS interact with and influence different social and economic conditions to, in turn, disrupt and mediate patterns of ill-health. Scholars also suggest many studies focus on linear approaches to modelling cause and effect without disentangling the interaction between multiple agents across different scales and unpacking the implications for the design and development of effective policy responses (Rutter et al., 2017; Pearce, 2018; Alberti et al., 2016; Curtis, 2010).

To fill this gap, this chapter adopts an innovative mixed-method approach to untangle the complex relationship between different types of ecological domains and their ecosystem services and health outcome indicators (such as all-cause, cardiovascular, respiratory and infant mortality). The paper also examines how different attributes of NBS such as the types of governance, the stakeholders , and different participatory methods influence health outcomes in cities.

6.2 Current understandings about the relationship between health and Nature Based Solutions (NBS)

6.2.1 The concept of health and health Inequality

Health is a complex, socially constructed concept that is open to different interpretations and definitions (Curtis, 2004; Gatrell and Elliott, 2014). It is described as a state of physical, mental and social well-being and a resource for everyday life (WHO, 1948) that allows people to function and participate in activities as members of society (McCartney et al., 2019). Gatrell and Elliot (2014) propose that the definition of health should also reflect the availability of

resources (personal and societal) that allow us to cope with or manage health or alter the environment to do so. Inequity in health reflects unfair differences in health due to a lack of resources and is an issue of social injustice. This concept is primarily used in the USA, while in Europe the term health inequality is used.

In this chapter, health inequalities are conceptualised as '*systematic differences in the health of people that occupy different positions in society*' (Graham, 2009, p3) that are often associated with differences in socio-economic position, ethnicity and gender that are socially produced, unfair and unjust (Bambra, 2016; Whitehead, 2007). Graham (2009) argues that people in poor health are not randomly distributed. In urban settings, the pattern of distribution in health is influenced by social, political and economic factors that shape the circumstances in which people grow, live, work, and age (Kjellstrom and Mercado, 2008; CSDH, 2008; Solar and Urwin, 2010). Gatzeweiller et al., (2017) also suggest that the rise in adverse health outcomes and inequalities in cities is due to a failure to take a systems approach to disentangle the complex interrelationships between climate, urbanisation and health in cities and a lack of integrated, transdisciplinary action to address the upstream causes of ill health.

6.3 The relationship between characteristics of NBS and health outcomes

6.3.1 The role of ecological domains

In cities, the built and natural environment are important determinants of health, particularly among groups that are disadvantaged by relative poverty, unemployment, low status, gender, ethnicity and disability (WHO, 2012). There is substantial literature on the role of green and blue space provided by NBS play in influencing health and well-being (see Lovell et al., (2018), Hartig at el. (2014) Markevych et al., (2017) and WHO, (2017). It is not the intention of this paper to review all of this literature, but a review by Lovell et al., (2018) and systematic reviews of quantitative studies by White et al., (2021) and Gascon et al., (2017) suggested that green and blue space provided by NBS play important roles in influencing both physical and mental health. Exposure to green or contact with nature may also reduce the risk of NCDs such as cardiovascular disease or all-cause mortality, especially in areas that lack greenery or access to greenspace space (see Table 6-1 for a summary of the key literature).

Evidence of a relationship between type of ecological domain and health	**Source**
Green exposure improves general health and may reduce the risk of cardiovascular disease (CVD) and stroke in areas that lack greenery or have poor access to greenspace, particularly groups with low socio-economic status. Exposure to NBS also associated with reductions in diastolic blood pressure, heart rate, salivary cortisol, type II diabetes, and obesity, and the prevalence of mental health conditions.	Dadvand et al., 2016; Sugiyama et al., 2008; James et al., 2015; Sandifer et al., 2015; Mitchel and Popham, 2008; Hu et al., 2008.Mass et al., 2009; Twohig-Bennett and Jones, 2018; Luo et al., 2020; Barton and Rogerson, 2017; Gascon et al., 2015.
Maternal exposure to NBS may help to protect against infant mortality, low birth weight and improve child behavioural development.	Schinasi et al., 2019; Agay-Shay et al., 2014; Markevych et al., 2014.
Contact with nature can build capacity by improving physiological health through increased physical activity and provide restorative effects that reduce levels of depression, anxiety, and psychological distress. Vegetation provided by NBS in a residential setting plays also plays a role in inducing patterns of 'healthy' cortisol associated with stress reduction. Physiological responses to stress have been implicated in increased risk of several diseases such as stroke or heart disease which may be mediated by greenspace.	Hartig et al.,2014; Mass et al., 2009; Mitchel, 2013. Chalmin-Pui et al., 2021 Mitchell and Popham, 2008
Improved access and facilities for recreation and physical activity provided by NBS may reduce the incidence of CVD, diabetes and other chronic illnesses.	Villeneuve et al., 2012; Michell et al., 2011; Brown et al., 2016.
NBS that feature lakes or NBS that are deployed along estuaries or seacoasts can reduce all-cause mortality and protect against ischemic and respiratory diseases in women and the elderly.	Crouse et al., 2018; Pasanen et al., 2019. Wheeler, 2012; 2015; White et al., 2013; Dzhambov, et al., 2018; White et al., 2021; Gascon et al., 2017

Living near to or regularly visiting freshwater or marine environments also promotes physical activity, particularly in the elderly, and improves mental and social health.	
NBS that provide views of blue spaces from home evoke feelings of attentiveness. The sounds of calm water can also be restorative and could play a role in psychological restoration and capacity building.	Ulrich, 1981; Gason, et al., 2015; Volker and Kistermann, 2015; Foley and Kistemann, 2015.
SUDS may influence health by helping citizens to reconnect with urban nature and reduce psychological stress by involving citizens in the maintenance of these greenspaces	Miro et al., 2018
Urban space that consists of derelict or vacant land is negatively associated with health. Regreening these spaces improves self-reported mental health, may reduce the heart rate and acute stress.	Garvin et al., 2013; South et al., 2018; 2015.
Allotment or community gardening can help address both chronic and NCDs, and mental health problems.	Soga, et al., 2017; Genter, et al., 2015; Gason, et al., 2015; Hartig et al., 2014, Clatworothy et al., 2013.

Table 6-1 Summary of literature that links NBS and health

Another pathway through which NBS may influence health is the creation of 'equigenic' properties provided by salutogenic resources that reduce the effect of environmental inequalities such as air pollution, climate change and other hazards (Mitchell et al., 2015; Jennings et al., 2012). Lee and Maheswaran, (2011) suggest that salutogenic effects of NBS not only aid in the recovery of acute and chronic stress but can also indirectly influence adverse health outcomes associated with CVD, gastroenterological, immunological, and neurological disease.

6.4 Ecosystems Services

Other research that has examined the relationship between NBS and health has focused on the direct or indirect benefits of ecosystems services, particularly on the effect on psychological

and physiological effects of green space or contact with urban nature (Lindgren and Elmqvist, 2018). A growing body of research suggests that ecosystems services that regulate climate (heat) and air quality modify risk factors associated with mortality due to heart or respiratory disease or all-cause mortality. Hartig et al., (2014) suggest that one potential causal pathway through which NBS may modify risk factors associated with all-cause and mortality due to CVD and respiratory disease is through the use of vegetation to reduce levels of air pollutants such as ozone, nitrogen oxides and particulate matter (PM)) (see Table 6-2 for an overview of the literature). However, it is important to note that air quality often exhibits a social gradient with areas of deprivation experiencing the highest levels of air pollution due to the combined effects of social differences in exposure and vulnerability (Fairburn et al., 2019). Thus, investment in different types of NBS that can regulate air temperate, and quality is especially important in these communities, but also in growing or shrinking cities where the demographic profile is skewed towards a growing young or elderly population. Scholars (Kovat and Hajat, 2008; Patz et al., 2005) argue that these groups are more vulnerable to heat-related mortality due to the synergist effects between intrinsic factors such as age and disability and extrinsic factors such as housing, but the inability of their thermoregulation systems to adapt to temperature extremes. Studies suggest the largest effect size is seen with increasing age (over 50 years) due to a decline in thermoregulation functioning of the body.

Relationship between ecosystems services and health	**Source**
Vegetation provided by NBS may regulate climate (heat) and air quality modifying risk factors associated with increased morbidity and mortality due to CDV, respiratory and deep vein thrombosis.	Pettit et al., 2017; Hartig et al., 2014; Periera, et al., 2012; et al., Bari et al., 2014.
NBS may mediate the effects of exposure to high levels of air pollutants in areas where there is an increased risk of children developin respiratory tract diseases.	Liu et al., 2017

NBS may prolong the pollen season altering atmospheric aero-allergenic load. This may increase the risk of asthma, sensitivity to allergic reactions and reduce lung functionality.	Aerts et al., 2020; Carinanos and Casares-Portel, 2011; Raymond et al., 2017.
Chronic or intermittent high exposures of CO_2 (<5,000 ppm) may also pose a risk to health through inflammation, reduction of cognitive ability, bone demineralisation, kidney calcification and non-obstructive coronary artery disease.	Jacobson et al., 2019.
NBS that regulate noise may reduce effects on the auditory system and mitigate adverse effects on blood pressure, cardiac output and stroke.	Munzel et al., 2014
NBS may mediate the impact of elevated temperatures associated with increased risk of heated-related mortality due to CVD, and respiratory and cerebrovascular disease.	Basu, 2008
NBS that improve water quality may reduce exposure to chemicals in water that can lead to a host of chronic diseases such as cancer and CVD, but also affect neurological development in children.	Levallois and Villaneuva, 2014.
Regulatory ecosystems services for coastal protection and flooding may help to prevent all-cause mortality and reduce incidence of CVD, stroke and myocardial infarction that are associated with flood or storm events. Reducing the incidence or severity of impact of these events may also mitigate psychological effects associated with these hazards.	Saulnier et al., 2017; Levallois and Villaneuva, 2014. French et al., 2019
Cultural ecosystem services provided by NBS may also help prevent CVD, reduce obesity and diabetes through the provision of opportunities for recreation and physical exercise.	Mackenbach et al., 2014; Pereira et al., 2012
Provisional ecosystem services such as food growing influence health by providing opportunities for physical labour, social connectedness and psychological rehabilitation. Growing number of studies also suggest this is important for serious health problems such as cancer, chronic inflammatory disease	Sempik, 2010; Clatworothy et al., 2013. See Organic et al., 2014 for review.

and HIV/AIDS, but also reduction of comorbidities that are associated with obesity, CVD, stroke and type II diabetes.	
Biodiversity loss and adverse health effects including epidemics of chronic inflammatory disease such as autoimmune disease, inflammatory bowel disease, cancer and mental health problems. Exposure to beneficial microbiota in early life can positively influence development of the immune system and amplify the stress-reducing effect of NBS.	von Hertzen et al., 2015 Arts et al., 2018

Table 6-2 Summary of literature that links different types of ecosystems services provided by NBS and health

6.5 The relationship between NBS, health and gender

Stafford et al., (2005), WHO (2014), Bird and Rieker (2008) suggest physiological differences in vulnerability to disease, the dose-response and the way in which men and women perceive their environment differently may influence the relationship between gender, climate, and health. Other research also suggests that the synergistic effects of temperate and heat combined with social and physiology differences in exposure and vulnerability in men and women. This has led some scholars to suggest that gender, age and ethnicity may also influence the dose-effect relationship between NBS and health (Fairburn et al., 2019; Cushing and Sorensen, 2021; Payne, 2016; Markevych et al., 2017). However, the evidence is not conclusive and other studies suggest that these differences may be explained by gendered differences in perceptions of and patterns of usage of greenspace (Roe et al., 2013; Currie et al., 2016; Markevych et al., 2017). For example, a study by Astell-Burt (2014) also suggests that gender-related benefits may be age-related with men experiencing benefits from early adulthood, but in women, NBS only appear to protect women's mental well-being from middle to older age. In other studies, the relationship between the size (see Richardson and Mitchell (2010), frequency of use (Reklaitiene et al., (2014), proximity (Astell-Burt et al., 2014; Weimann et al., 2019) or the amount of leisure time spent in NBS (Wannamethee et al., 2000, 2001; Lemaitre et al., 1999) influenced the relationship between gender, NBS and health particularly CVD in middle age.

NBS in institutional settings may also play a role in modifying the risk of exposure and effects of indoor $PM_{2.5}$ and attenuating noise pollution (Mueller et al., 2017) due to their 'equigenic' properties (Mitchell et al., 2015; Jennings et al., 2012).

6.6 Data and methodology

This study adopts a novel approach to begin to explore the interactions between different types of NBS, the ecosystems services that they create, and the role of governance, participation and citizen involvement and adverse health outcomes in cities. To achieve this, the study adopts the city as a unit of analysis (Chapter 3) to explore the influence of different types of NBS and adverse health outcomes using inferential statistics and quantitative text analysis in parallel. In doing so, it is not the intention of this study to infer a statistical association between different characteristics of NBS and cause-related and all-cause mortality variables but begin to explore how different aspects of NBS may influence health.

6.6.1 Data sources

6.6.1.1 Characteristics of NBS

To investigate how different types of greenspaces provided by NBS and the ecosystem services they provide relate to health outcomes, categorical variables that report the frequency of count for each type of ecological domain, ecosystem service, modes of governance, stakeholder involvement and mode of participatory engagement selected for analysis. Table 6-3 summarises each of the different categorical variables that represent different characteristics of NBS that are published in the UNA that are used in the study. Count frequencies for each indicator were extracted from the UNA for the reference years 2011 and 2016 based on availability of mortality indicators (see Chapter 5).

Characteristics of NBS (based on definitions developed by Almassy et al., 2017)	
Ecological Domains	
External green buildings – an aggregated category including green roofs, green walls or facades, balcony green other types of external green buildings.	Urban grey infrastructure connected to green space – an aggregated category including the following subcategories: alley and street trees/hedges/greens, railroad bank and tracks, house gardens, green playground or school grounds, institutional green space, green parking lots, riverbank greens, and other types of urban grey connect green space.
Urban parks and semi-natural areas – an aggregated category consisting of large urban parks or forests, pocket parks or neighbourhood green spaces, botanical gardens, green corridors and other types of parks or urban forests.	Allotment and community gardens – an aggregated category consisting of allotments, community gardens, horticulture and other types of allotments or community gardens.
Blue areas – an aggregated category consisting of lake/pond, river/stream/canal/estuary, delta, sea coast, wetland/bog/fen/marsh and blue areas other	Indoor greens – an aggregated category consisting of indoor vertical greeneries (walls and ceilings), atriums and other types of indoor green areas.
Green areas for water management – an aggregated category consisting of rain gardens, swales / filter strips, sustainable urban drainage systems, and other types of green areas for water management.	Derelict areas is an aggregated category consisting of abandoned and derelict spaces with growth of wilderness or green features.
Ecosystem services are divided into four groups of variables:	
Provisional ecosystem services – individual variables representing the frequency of	Regulatory ecosystem services – individual variables representing the frequency of

services for food production, raw materials, freshwater quantity, medical resources or other types of provisional services provided by NBS.	local climate regulation (temperature reduction), air quality regulation, coastal protection, noise reduction, carbon storage/sequestration, flood regulation, water purification, pollination, or other types of regulatory ecosystem services.
Habitat ecosystems services – individual variables that represent the frequency of habitats created for species, actions to the maintenance of genetic diversity or provide other types of habitat services.	Cultural ecosystem services – individual variables that representing the frequency of recreation and mental and physical health, tourism, aesthetic appreciation, inspiration for culture, art and design, and other types of cultural ecosystem services.
Modes of governance	
This group has three variables representing the number of NBS that are governed by: the state, governed using a hybrid form of governance or co-governed, or governance led by non-governmental organisations. A fourth variable identifies the type of non-governmental organisation that may consist of: the public sector, civic society, private companies, research institutions, community groups, multilateral organisations or other types of non-governmental actors leading the governance of NBS.	
Key actor involved in NBS	
This group has several variables representing the number of different stakeholders that are involved with NBS: multilateral organisations, the EU, national, regional or local government, public sector, non-governmental organisations, business associations, private sector, private foundations, transnational networks, research, community groups, or other types of key actors involved.	
Key actor instigating NBS	
This group has several variables representing the number of different stakeholders that instigate NBS: multilateral organisations, the EU, national, regional, or local government, public sector, non-governmental organisations, business associations, private sector, private	

foundations, transnational networks, research, community groups, or other types of key actors involved.
Modes of citizen participation and involvement
This group has several variables representing different modes of participation including co-planning, crowdsource funding or participatory budgeting, taskforce group, dissemination information education, consultation e.g., workshop surveys, joint implementation of NBS, joint management of NBS, citizen oversight, citizen science, citizen monitoring review or other types of citizen participation. A second of group of variables includes the methods used to involve citizens in the evaluation of NBS including questionnaires, interviews, focus groups, online forums, submission of monitoring data (citizen observations) or other type.

Table 6-3 Characteristics of NBS (based on categorisation developed by Almassy et al., 2017)

6.6.1.2 Mortality indicators

Mortality patterns are determined by several different factors including age, living conditions, surrounding environment, but also lifestyle choices. All-cause and cause-specific mortality are important metrics in population health; data on rate, cause and numbers of deaths categorised by sex-linked biology, age and location provide valuable intelligence for policy debate, conceptualisation and planning of interventions. Thus, in this study, the relationship between different characteristics of NBS and cause-specific, all-cause, and all-cause mortality sex-linked biological measures are investigated. Table 6-4 lists the mortality indicators extracted from the Urban Audit (Eurostat, 2017) represent synthetic indicators based on standardised death rates calculated by each member state based on analysis of the classification of causes of death using the International Statistical Classification of Diseases and Related Health Problems (Eurostat, 2004; European Union, 2018).

Some scholars are critical of their use as a measure of the effectiveness of health systems or public health interventions since they do not accurately represent specific illnesses or measure the effectiveness of a health intervention being adopted, or may not be comparable between

and within states or cities (Allin and Grigon, 2014; Lavergne and McGrail, 2013). Lozano et al., (2013) argue that the variability of public health structures across Europe, both within and between countries, leads to variations in institutional frameworks for reporting and different approaches to cause-of-death assessments being applied. Springer et al. (2012) also highlight the limitations of specific variables such as all-cause mortality related to sex-linked biological measures; these authors argue that sex-linked biological constructs should not be used as proxies for gender since sex and gender are based on different constructs (see Chapter 2). Despite these limitations, mortality indicators for cities published in the Urban Audit are one of the few pan-European health datasets available for cities. Hence, they are used in this study to begin to explore the relationship between population health and different characteristics of NBS.

Health outcome indicator (synthetic indicator based on standardised death rate)
All-cause mortality due to heart or respiratory disease
All-cause mortality in females under 65 years
All-cause mortality in men under 65 years
Infant mortality

Table 6-4 Health outcome indicators available for cities in the Urban Audit (*Eurostat, 2004)*

6.6.2 Statistical analysis

Based on Collette (2002) and Thoresen (2019), percentiles were used to categorise death counts for each mortality indicator allowing dummy variables to be created for analysis for the reference year 2011 and 2016. Dummy variables created using the Urban Audit data and indicators that represent each of the characteristics of NBS used in this study were brought together in a database to create two multiblock datasets for analysis, one for each reference year (Chapter 2). Using IBM SPSS Statistics for Windows (version 25.0), Pearson Chi-Squared Test was applied to investigate the relationship between each characteristic of NBS and each mortality indicator for each reference year and the results were compared to explore how these relationships vary temporally.

One key limitation of the study is that it was not possible to adjust for confounding using Pearson's Chi-Squared or test the statistical association between different variables and different characteristics of NBS using these tests. Despite this limitation, our study calculated Cramers v effect size to begin to investigate the strength of the of the relationship between different characteristics of NBS and mortality indicators (Cohen, 1988; Sheskin, 2011). Effect size is helpful because it helps us to understand the magnitude of the influence or treatment effect of the variable by examining the strength of the relationship. However, it does not tell us about the degree of exposure to intervention or treatment effect (Cohen, 1988). Interpretation of effect sizes was based on Cohen (1998) who classified effect sizes based on the following benchmarks: small (w=0.2), medium (w=0.5) and large (w=0.8).

In parallel, textual commentaries that accompanied the binary indicators published in the UNA were analysed using KH Coder (Higuchi, 2016) to add further insight into these exploratory results. This data was collected by MSc students as part of the data collection phase of the Naturvation project (Chapter 2). Textual data that could not be classified into binary indicators was used by Naturvation to create an 'other' category indicator for each type of ecological domain and ecosystem service. These commentaries together with qualitative data about institutional actors that were involved in NBS, and modes of participation were thematically coded was completed based on an analysis of the occurrence of word frequencies and themes identified through a review of the literature on the relationship between green and blue space and health and well-being. Using a word-based approach, the study utilised two methods of texting mining, multidimensional scaling and co-occurrence network analysis, to reduce the dimensionality of the data and visualise how networked structure (Quine, 1980).

6.7 The relationship between the characteristics of NBS and mortality indicators

6.7.1 The relationship between different types of ecological domains and mortality

Analysis of the relationship between the frequency of ecological domains and mortality due to cardiac or respiratory disease in 2016 and 2011 suggests some types of external green buildings such as green roofs and green walls, large urban parks and botanical gardens, seacoasts and

green balconies are significantly associated at p-value 0.05 or 0.10. Of the external green buildings, only green walls were consistently associated with mortality due to cardiovascular disease in 2011 and 2016 with a moderate effect size based on Cohen (1988). The study also found a moderate to strong size effect between all-cause mortality and blue spaces such as wetlands or fens, NBS connected to residential properties and derelict land or vacant plots with wild areas. However, of these ecological domains, only derelict areas with wild areas increased the size of the effect between 2011 and 2016 (see Table 6-5).

Table 6-5 shows that a range of ecological domains were associated with all-cause mortality in females and males in 2011 and 2016. In females under 65 years of age, all-cause mortality was highly significantly related to green balconies, large urban parks, seacoasts in 2011 and 2016 with the effect size increasing slightly in 2016. However, the size of the sample for green balconies is relatively small and hence should be interpreted with caution. In comparison, NBS associated with rivers, streams or estuaries, institutional greenspace and derelict or abandoned areas with greenspace were significantly related only in 2016, but the effect size was only small to moderate (Table 6-5). In contrast, all-cause mortality in males under 65 years of age was also significantly related to also suggested that green balconies and sea coasts but green balconies were significantly related in 2011 and 2016 (see Table 6-5). Large urban parks were related to all-cause mortality in men in 2011, but the size of the effect was much weaker in males than females. Unlike all-cause mortality in females, sustainable urban drainage schemes (SUDS) were significantly related to mortality in males with the effect size slightly increasing between 2011 and 2016.

	Pearson's Chi-squared (X^2)	**Degrees of freedom (df)**	**Sample size (n)**	**Size effect based on Cramer's v (w)**	**Significance level**	**Pearson's Chi-squared (X^2)**	**Degrees of freedom (df)**	**Sample size (n)**	**Size effect based on Cramer's v (w)**	**Significance level**
Type of ecological domain	Mortality due to heart or respiratory disease (2016)					Mortality due to heart or respiratory disease (2011)				
Green roof	-	-	-	-	-	21.70	12	67	0.33	0.04
Green walls	30.71	9	58	0.42	0.00	17.62	9	58	0.32	0.04

Green balconies	7.01	2	15	**0.68**	0.03	-	-	-	-	-
Urban Park	-	-	-	-	-	29.24	51	91	0.33	0.01
Botanical garden	-	-	-	-	-	10.12	2	21	**0.69**	0.06
Sea coasts	-	-	-	-	-	11.34	4	21	**0.52**	0.02
	All-cause mortality (2016)					All-cause mortality (2011)				
Wetlands such as fens, bogs or marshes	-	-	-	-	-	58.09	50	50	**0.54**	0.05
House garden	-	-	-	-	-	2.76	1	13	**0.73**	0.09
Indoor Vertical Greeneries	-	-	-	-	-	4.71	2	18	**0.49**	0.09
derelict or abandoned spaces with greenspace	38.74	54	1	0.74	0.01	52.66	15	15	**0.57**	0.00
	All-cause mortality in females under 65 years (2016)					All-cause mortality in females under 65 years (2011)				
Green balconies	15.0	4	15	1.0	0.05	9.23	3	15	**0.78**	0.03
Large urban parks	22.57	15	91	0.50	0.09	24.03	15	91	**0.51**	0.06
Sea coasts	23.250	6	21	0.74	0.01	21.48	6	21	**0.71**	0.02
Derelict or abandoned spaces with wild areas	38.74	15	54	**0.49**	0.01					
Institutional greenspaces	14.82	8	48	0.39	0.06					
Rivers, streams or estuaries	21.13	12	69	0.32	0.05					
	All-cause mortality in males under 65 years (2016)					All-cause mortality in males under 65 years (2011)				
Green walls	40.02	24	58	**0.48**	0.02	36.73	24	58	**0.46**	0.05
Green Balconies	15.00	4	15	1.0	0.01	15.00	4	15	1.0	0.00
Large urban parks	58.84	91	40	0.34	0.08	-	-	-	-	-
Sea coasts	-	-	-	-	-	23.25	8	21	1.0	0.00
SUDS	43.66	28	59	0.43	0.03	8.58	59	4	0.38	0.07
	Infant mortality (2016)					Infant mortality (2011)				
Green Corridor	16.23	8	64	0.36	0.04	16.23	8	64	0.36	0.04
Other type of park	8.97	3	29	**0.56**	0.03	8.97	3	29	**0.56**	0.03
Wetlands, bogs or marshes	15.99	4	50	**0.57**	0.03					
Derelict spaces or vacant lots with wild areas	33.95	8	56	**0.48**	0.01	32.78	10	56	**0.54**	0.00

Table 6-5Association and size effect between ecological domains and a) mortality due to heart or respiratory disease and b) all-cause mortality (large size effect in bold).

In comparison to mortality due to cardiovascular or respiratory disease wetlands, house gardens and indoor vertical greeneries were strongly related with all-cause mortality, but not in 2016. Only derelict land with wild areas was strongly related to all-cause mortality with the effect size increasing between 2011 and 2016. The study also examined the relationship between different types of ecological domains and all-cause mortality linked to biological sex. The study also examined the relationship between infant mortality and different types of ecological domains. Green corridors, 'other' types of park, and derelict land with wild areas were significantly related to infant mortality in 2011 and 2016 with the effect size remaining consistent. Wetlands, bogs, or marshes were also strongly related to infant mortality, but only in 2016.

To parallel, the research used multidimensional scaling to analyse thematic codes in the unstructured textual data that accompanied the 'other' type of each category of the ecological domain to examine the interrelationship between health and different types of NBS. Figure 6.1 shows a three-dimensional scatter diagram of the interrelationship between different groups of words that are clustered based on similar jacquard co-efficient. The diagram shows that different types of the ecological domain (including urban parks and forests, external green buildings, SUDS and different forms of urban gardening), opportunities for recreation and increasing urban biodiversity have a similar co-occurrence pattern. This suggests these types of ecological domain are related to those NBS that aim to provide opportunities to improve health whilst also improving biodiversity. However, closer examination of their pattern of similarity (see Figure 6.2) suggests the pattern of co-occurrence is strongest between clusters that relate to urban development and rejuvenation agendas linked with increasing green space while opportunities for recreation for health and well-being appear as a secondary consideration.

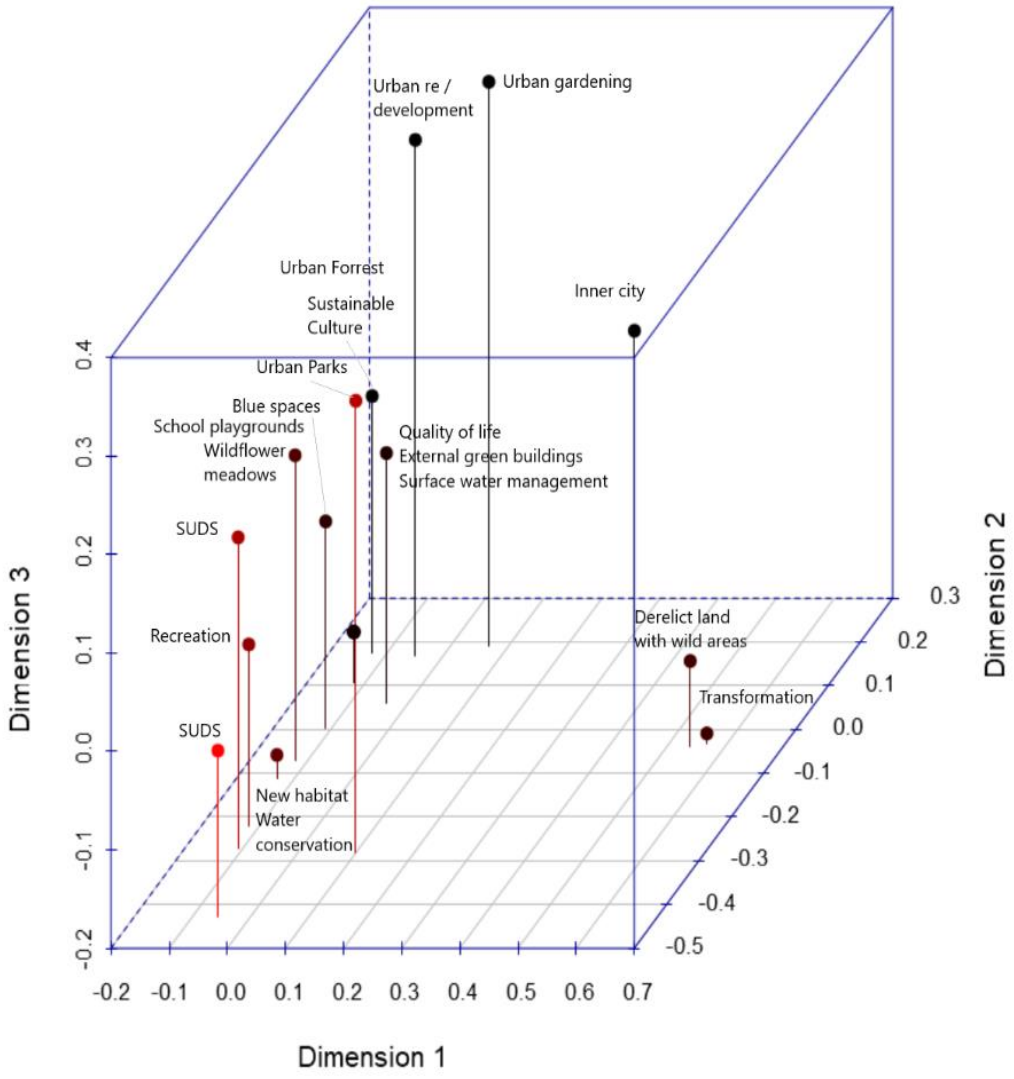

Figure 6-1 Multidimensional scaling of other types of ecological domain

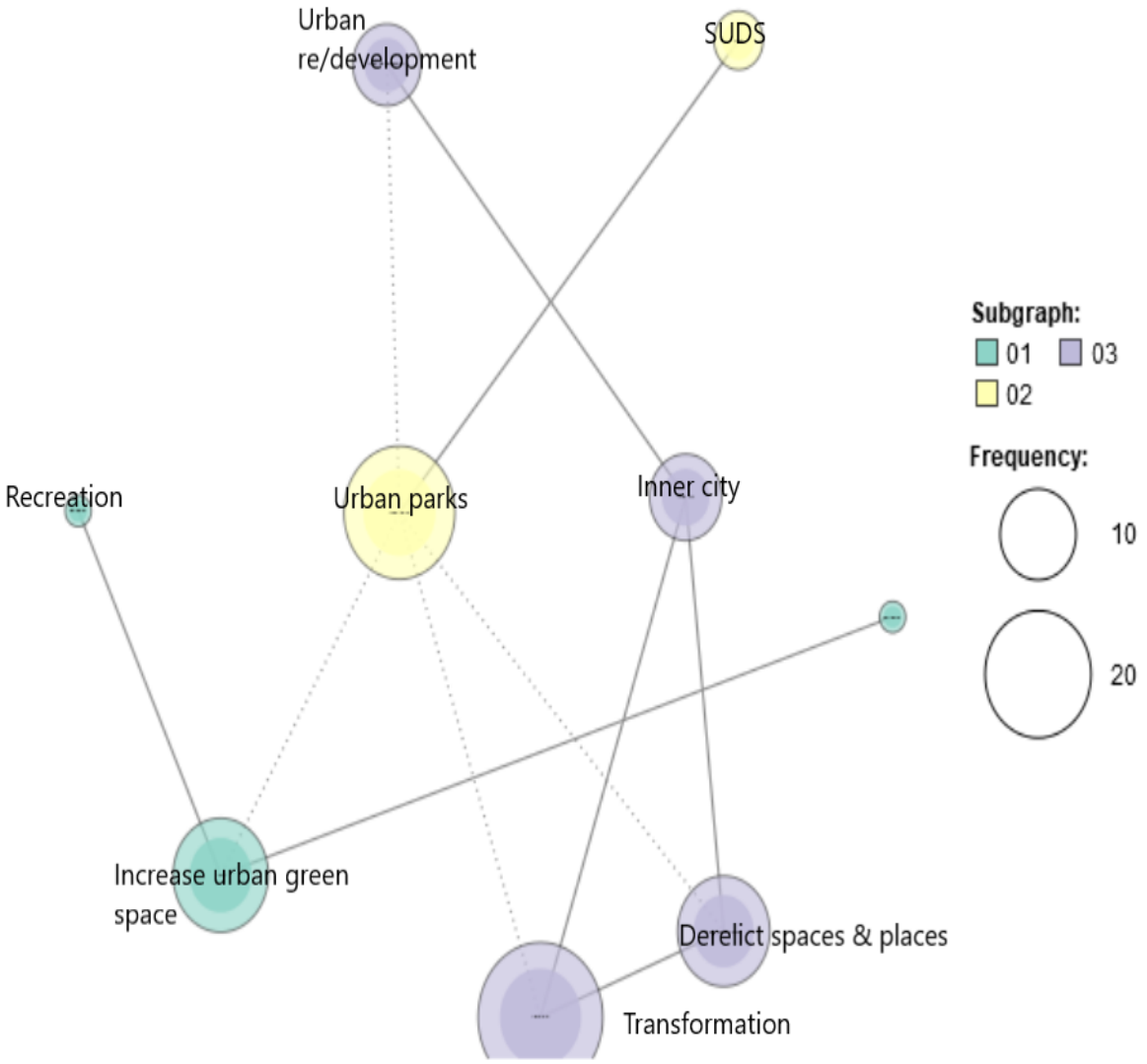

Figure 6-2 Co-occurrence network analysis of 'other' types of ecological domains

6.7.2 The role of ecosystems services

Only three variables were significantly related to mortality due to heart or respiratory disease, namely medical resources and noise reduction with a strong size effect and aesthetic appreciation with a moderate size effect (see Table 6-6).

	Pearsons Chi-squared (X^2)	Degrees of freedom (df)	Sample size (n)	Size effect based on Cramer's V	Significance level	Pearsons Chi-squared (X^2)	Degrees of freedom (df)	Sample size (n)	Size effect based on Cramer's V	Significance level
Type of ecosystem service	Mortality due to heart or respiratory disease (2016)					Mortality due to heart or respiratory disease (2011)				
Medical resources	3.61	1	13	**0.53**	0.06	-	-	-	-	-
Noise reduction	60.46	15	56	**0.6**	0.00	-	-	-	-	-
Inspiration	-	-	-	-	-	32.09	21	79	0.39	0.02
	All-cause mortality (2016)					All-cause mortality (2011)				
Food production	30.71	21	83	0.35	0.08	-	-	-	-	-
Climate Regulation	50.79	24	84	**0.78**	0.01	51.68	24	85	0.45	0.01
Flood Regulation	-	-	-	-	-	31.59	21	77	0.37	0.06
Regulation other	-	-	-	-	-	12.25	6	39	0.40	0.05
Habitat Supporting Service Other	15.2	4	12	**0.79**	0.04	4.80	2	12	**0.63**	0.09
Aesthetic appreciation	30.70	21	83	0.35	0.08	48.49	27	98	0.40	0.07
Inspiration for art, culture and design	42.26	21	77	**0.74**	0.04	-	-	-	-	-
	All-cause mortality in females under 65 years (2016)					All-cause mortality in females under 65 years (2011)				
Medical resources	9.24	4	13	**0.84**	0.06	8.78	4	13	**0.82**	0.07
Climate regulation	47.92	32	86	0.37	0.04	92.10	64	26	0.33	0.07
Coastal protection	29.74	12	26	**0.61**	0.03	-	-	-	-	-
Air Quality Regulation	54.92	36	89	0.39	0.02	-	-	-	-	-
Noise Reduction	73.78	20	56	**0.57**	0.00	69.30	20	56	**0.56**	0.00
Genetic diversity	48.82	36	85	0.38	0.07	-	-	-	-	-
Aesthetic appearance	49.77	36	99	0.36	0.06	-	-	-	-	-
Cultural Ecosystem Services Other	36.53	24	83	0.33	0.05	-	-	-	-	-
	All-cause mortality in males under 65 years (2016)					All-cause mortality in males under 65 years (2011)				
Climate regulation	95.33	72	86	0.37	0.03	-	-	-	-	-
Noise Reduction	78.11	40	56	**0.53**	0.00	50.79	35	56	0.43	0.04
Pollination	55.85	36	46	0.45	0.02	-	-	-	-	-
Other type of regulatory service	21.35	14	39	**0.52**	0.09	-	-	-	-	-

Recreation, physical and mental health	91.23	72	99	0.34	0.06	-	-	-	-	-
Aesthetic appearance	112.33	72	83	0.37	0.02	-	-	-	-	-
	Infant mortality (2016)					Infant mortality (2011)				
Pollination	14.65	6	46	**0.69**	0.02	14.65	6	46	**0.69**	0.02

Table 6-6 Association and size effect between ecosystems services and mortality indicators (bold text indicates large effect size)

In comparison, a range of different provisional, regulatory, habitat supporting, and cultural ecosystems services were weakly to moderately related to all-cause mortality. Urban food production was the only provisional ecosystem service that was significantly related to all-cause mortality with a moderate size effect of 0.35 at p-value 0.08. The study also found the regulation of heat by NBS was also significantly related to all-cause mortality with a significant increase in the size of the effect being observed between 2016 and 2011. Two other types of regulatory services were also significantly related to all-cause mortality, namely, flood regulation and 'other' types of regulatory service each with a moderate effect size. Co-occurrence network analysis of the qualitative data that accompanies the 'other' type of ecosystem service in Figure 6.3 shows that there are two distinct clusters NBS with co-occurring ecosystems services; those that aim to simultaneously provide regulate climate, carbon and flooding while regenerating urban infrastructure (shown in green) and (see Figure 6.3).

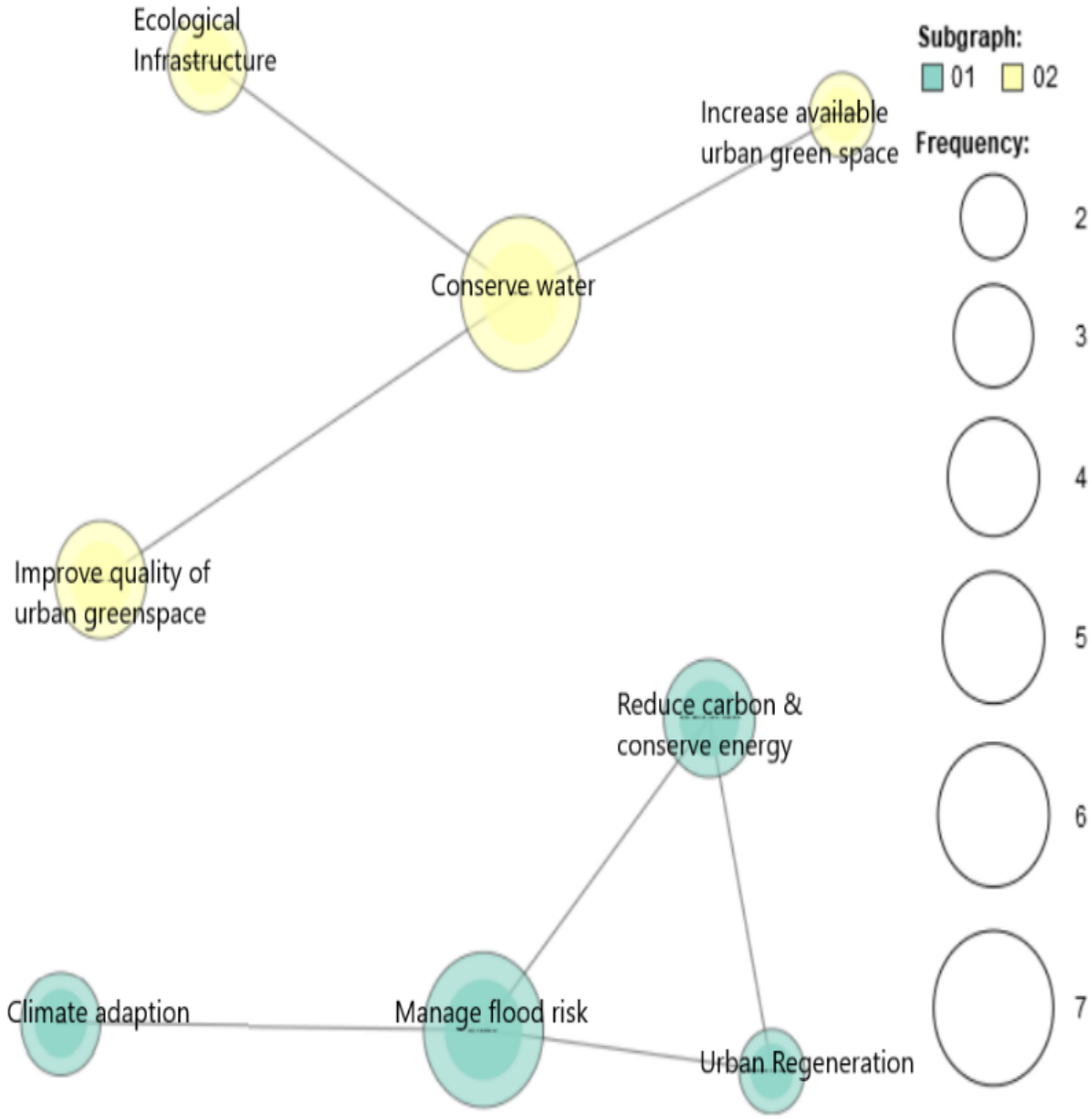

Figure 6-3 Co-occurrence network of 'other' type of regulatory ecosystems services

‘Other’ type of habitat supporting services were also significantly related to all-cause mortality with a strong size effect observed in 2011 and 2016; although these results should be interpretated with caution due to the small sample size. Two types of cultural ecosystem service were also related to all-cause mortality, namely aesthetic appreciation and inspiration for art, culture and design. The results suggest that the moderate size of the effect of aesthetic appreciation slightly declined between 2011 and 2016 which may be linked to the withdrawal of project-based funding following austerity urbanism. Inspiration for art, culture and design was only significantly related in 2016 with a strong effect size of 0.74 at p-value 0.04.

As with ecological domains, there are similarities and differences in the relationship between all-cause mortality related to biological sex and different types of ecosystem service. The results suggest that regulatory and cultural ecosystems services are mainly related to mortality in males and females under 65 years of age. Table 6-6 shows that noise reduction, climate regulation, and aesthetic appearance were moderately to strongly related in both mortality in males and females. However, the study also found there were differences; all-cause mortality in females was strongly related to coastal protection, but moderately related to air quality regulation, genetic diversity, and ‘other’ type of cultural ecosystem service (such as education). None of these services were related to mortality in males, but all-cause mortality in males is weakly to moderately related to services for pollination, recreation, physical and mental health, and other types of regulatory ecosystem’s service. Infant mortality was only strongly related to services for pollination in both 2016 and 2011.

Analysis of the level of similarity of textual data that relates to ‘other’ types of provisional, regulatory, habitat supporting or cultural ecosystems services using Multidimensional Scaling provides further insight into the role that NBS play in supporting health outcomes in cities. Figure 6.4 shows that describe other types of ecosystem services provided by NBS with three groups are shown. The first, shaded green, provides services that aim to influence health and well-being by reconnecting citizens with urban nature or addressing social justice issues. The second cluster shaded yellow, aims to increase the availability of environmental resources to aid climate adaptation by improving access to greenspace for shade and communal areas to facilitate. The last cluster shaded purple suggests cities also aim to regenerate urban space and

create green growth, vocational training, and employment opportunities by co-creating these services. However, if we examine the strength of co-occurrence between these clusters (see Figure 6.5) the mode of centrality is strongest between the creation of urban greenspace and urban regeneration rather than health and well-being. This could be indicative of a link between green growth and beautification of cities. In contrast, NBS that aim to improve the liveability of cities co-occur with thematic codes that relate to the quality of urban greenspace and access to amenities such as communal spaces.

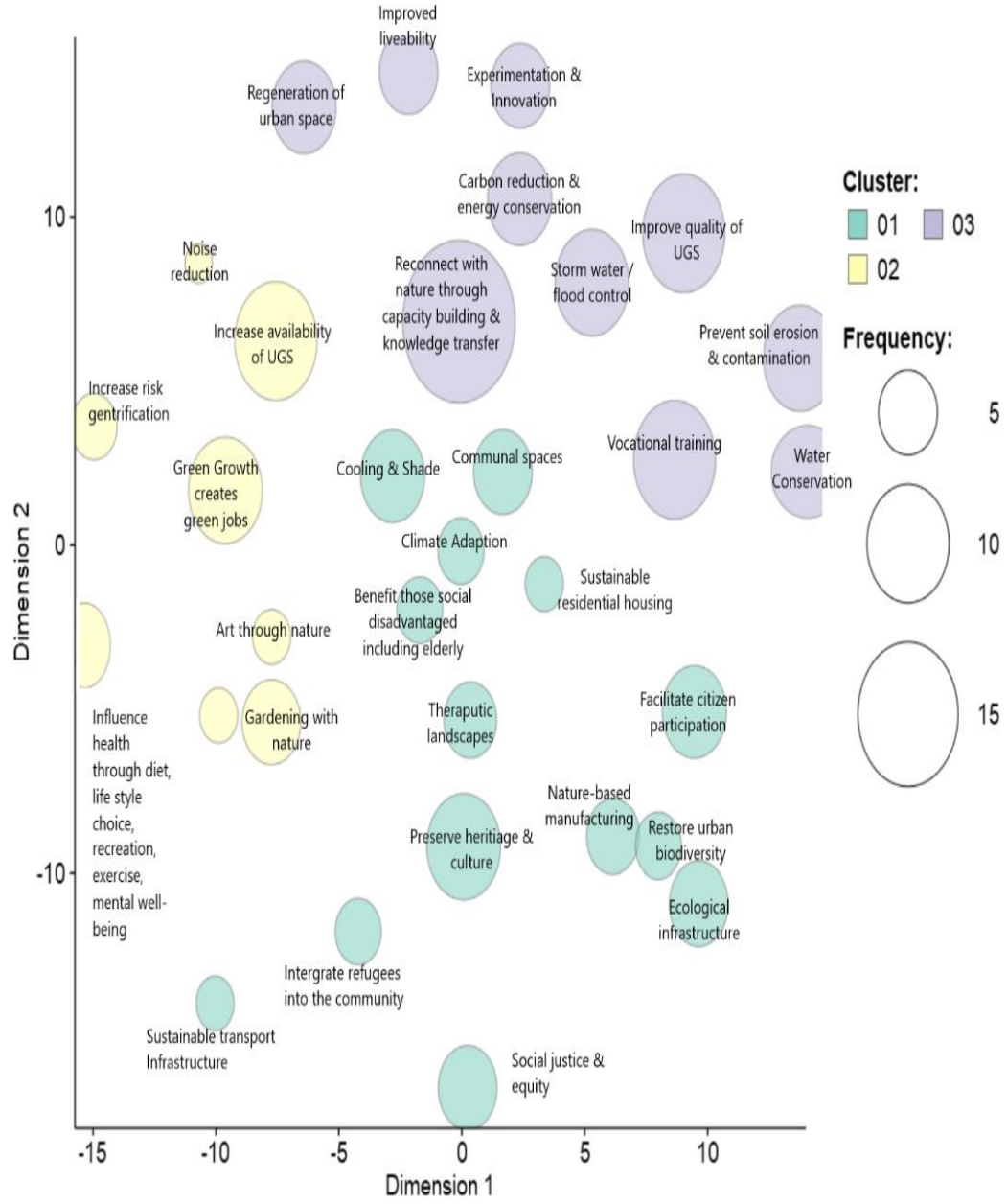

Figure 6-4 Multidimensional scaling of 'Other' Type of Ecosystem Services

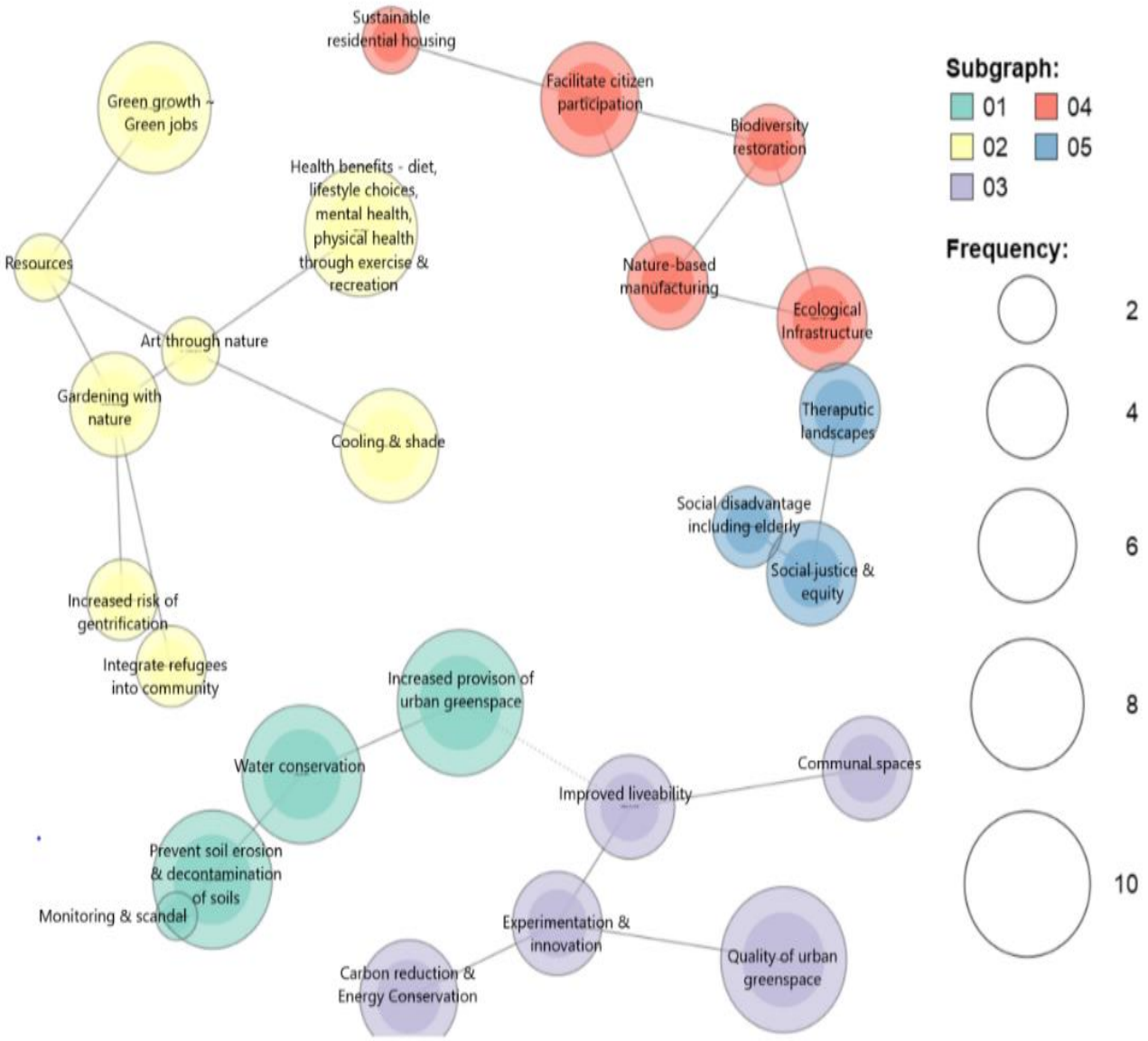

Figure 6-5 Co-Occurrence Network Analysis of 'Other' Type of Ecosystem Services

6.8 Key actors involved in NBS and participation on health outcomes

Overall, statistical analyse of the relationship between different types of governance adopted for NBS and different mortality indicators suggests that governance is largely unrelated to different health outcomes indicators. Apart from all-cause mortality in females under 65 years,

mortality due to cardiovascular or respiratory disease and infant mortality, different modes of governance adopted by NBS are largely unrelated to different health outcomes. Modes of governance led by non-government actors were weakly to moderately related to mortality due to cardiovascular or respiratory disease (2016 X^2=44.94 df=18 p0.00 n=94 w=0.39, 2011 X^2=29.80 df=18 p0.04 n=94 w=0.33). While all-cause mortality in females was significantly related to governance led by governmental actors (X^2=33.14 df=24 p0.07 n=87 w=0.32 2016), and governance led by non-governmental actors such as civic society ((X^2=37.61 df=24 p0.04 n=82 w=0.34). Infant mortality was related to governance of NBS by research institutions (X^2=16.36 df=8 p0.04 n=64 w=0.36).

Of the actors involved in the NBS, local authority and community groups or citizens were most commonly related to mortality indicators. Table 6-7 shows that these actors and private foundations were moderately to strongly related with mortality due to heart or respiratory disease and all-cause mortality in males under 65 years. All-cause mortality related to biological sex was moderately related to the involvement of community actors in NBS, but similarly differences were observed; actors from community groups were related to mortality in females while the involvement of research institutions and 'other' types of actors was related to mortality in males. The study also found that infant mortality is related to the involvement of public sector actors and NGO's reflecting that infant health programmes are often governed by community-based organisations with links to public health and local government.

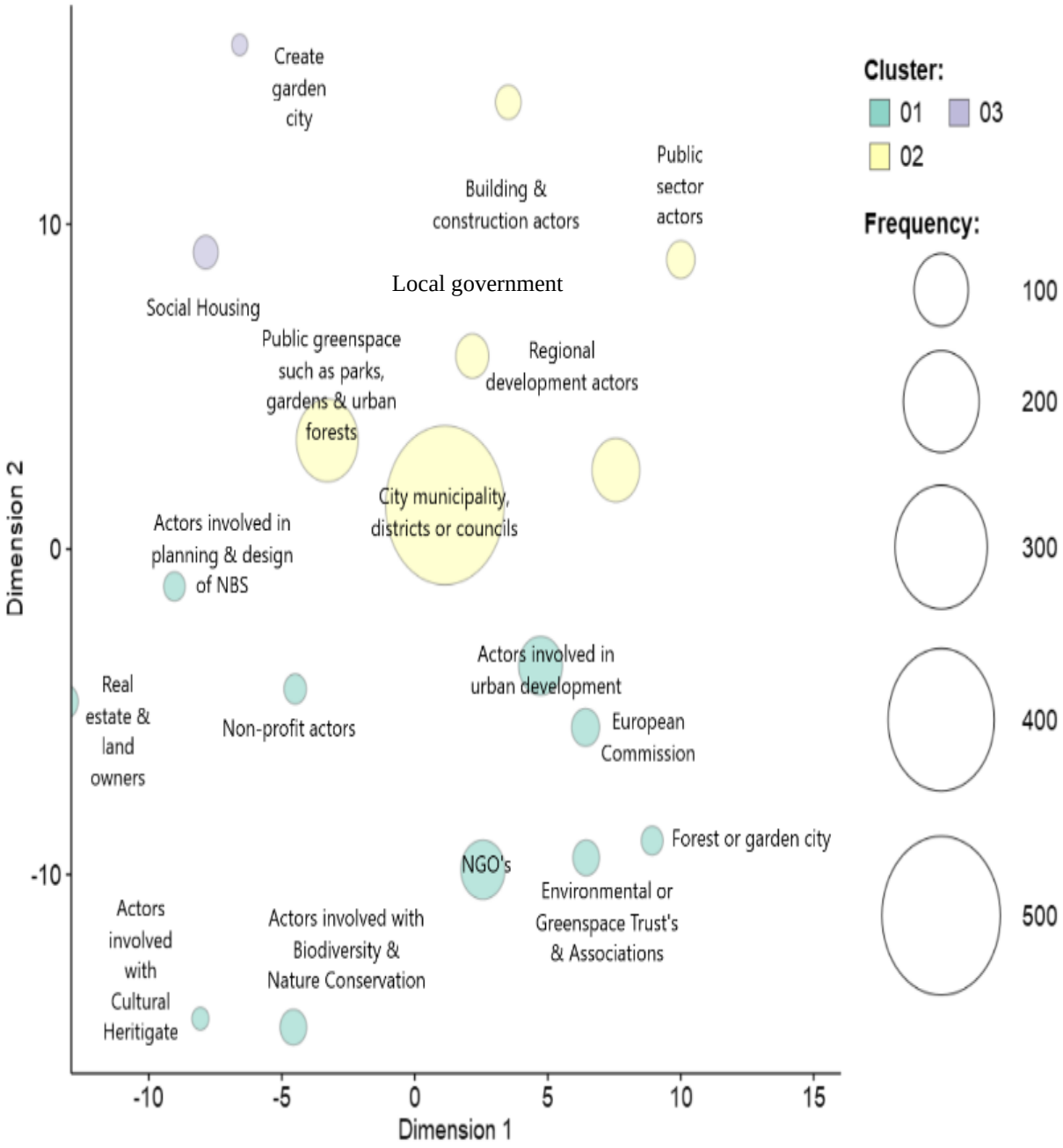

Figure 6-6Multidimensional scaling of the specific roles of actors involved in the governance of NBS

	Pearsons Chi-squared (X^2)	Degrees of freedom (df)	Sample size (n)	Size effect based on Cramer's v (w)	Significance level	Pearsons Chi-squared (X^2)	Degrees of freedom (df)	Sample size (n)	Size effect based on Cramer's v (w)	Significance level
Key actors involved in NBS	Mortality due to heart of respiratory disease (2016)					Mortality due to heart of respiratory disease (2011)				
Local authorities	49.74	21	99	0.41	0.00	39.60	21	99	0.37	0.08
Community groups or citizens	42.77	27	97	0.38	0.03	44.71	27	97	0.44	0.04
Private Foundations	34.34	10	35	**0.70**	0.00	-	-	-	-	-
	All-cause mortality in females (2016)					All-cause mortality in females (2011)				
Local authorities	-	-	-	-	-	78.88	56	99	0.34	0.04
Community groups or citizens	-	-	-	-	-	91.45	56	99	0.34	0.06
	All-cause mortality in males (2016)					All-cause mortality in males (2011)				
Local authorities	111.19	63	99	0.40	0.00	88.80	56	99	0.40	0.03
Research institutions	72.04	48	79	0.39	0.01	-	-	-	-	-
Other type of key actor	-	-	-	-	-	21.91	12		0.65	0.09
	Infant mortality (2016)					Infant mortality (2011)				
Public sector	20.74	12	80	0.36	0.05	-	-	-	-	-
NGO	35.46	16	89	**0.59**	0.03	-	-	-	-	-
Key actors instigating NBS	Mortality due to heart of respiratory disease (2016)					Mortality due to heart of respiratory disease (2011)				
Regional government	23.67	8	47	**0.53**	0.03	-	-	-	-	-
Private sector	43.73	12	80	0.43	0.00	-	-	-	-	-
	All-cause mortality in males (2016)					All-cause mortality in males (2011)				
Regional government	33.75	20	47	0.42	0.03	-	-	-	-	-
Private sector	68.68	36	80	**0.47**	0.00	70.92	32	80	0.46	0.00
Business	12.00	5	12	1.0	0.04	-	-	-	-	-
	All-cause mortality in females (2016)					All-cause mortality in females (2011)				
Private sector	39.54	16	80	0.35	0.01	41.26	16	80	0.35	0.01
	Infant mortality (2016)					Infants mortality (2011)				

Local authority	57.41	27	99	0.44	0.01	53.23	18	99	0.55	0.00
Private sector	9.11	4	80	0.34	0.06	-	-	-	-	-

Table 6-7Association and size effect between key actors involved in NBS and mortality indicators (bold text indicates large size effect)

While local authority and community actors involved in NBS are often associated with mortality indicators at a city-scale, the analysis suggests that actors from regional government and the private sector play an important role in initiating NBS that are related to health outcomes. Actors instigating NBS from regional government were strongly related to mortality due to heart or respiratory disease and all-cause mortality in males in 2016. In contrast, private sector actors that initiate NBS were moderately associated with mortality due to heart or respiratory disease, all-cause mortality in males and females and infant mortality. Business actors were strongly related to all-cause mortality in 2016 but these results should be interpretated with caution due to the small sample size. Local authority actors that initiate NBS were also strongly related to infant mortality in both 2016 and 2011.

In addition to examining the relationship between modes of governance and key actors that are involved in the management of, or instigation of NBS, the study also examined the relationship between the modes of participation and citizen involvement. Similarly, to different modes of governance, different forms of participation were largely unrelated to mortality variables, with the exception of all-cause mortality, mortality in males under 65 years and infant mortality. The study found that all-cause mortality was strongly related to participatory funding or crowd funding (X^2=23.20 df=15 p0.08 n=42 w=0.43 in 2016, X^2=18.61 df=10 p0.05 n=42 w=0.47 in 2011) and involvement with task forces (X^2=22.94 df=12 p0.03 n=43 w=0.42 in 2016, X^2=14.91 df=8 p0.06 n=43 w=0.42). All-cause mortality in males was also related to information dissemination activities but not females (X^2=111.44 df=81 p0.18 n=85 w=0.38) and infant mortality was related to joint management (X^2=31.99 df=6 p0.00 n=65 w=0.70 in 2016 and 2011). However, despite being largely unrelated to health outcome indicators, multidimensional scaling of the qualitative commentaries that accompany indicators about the modes of participation suggest actors from business, private companies, research, and water

utilities play a pivotal role in the implementation of modes of participation that engage citizens in active monitoring of NBS or citizen science.

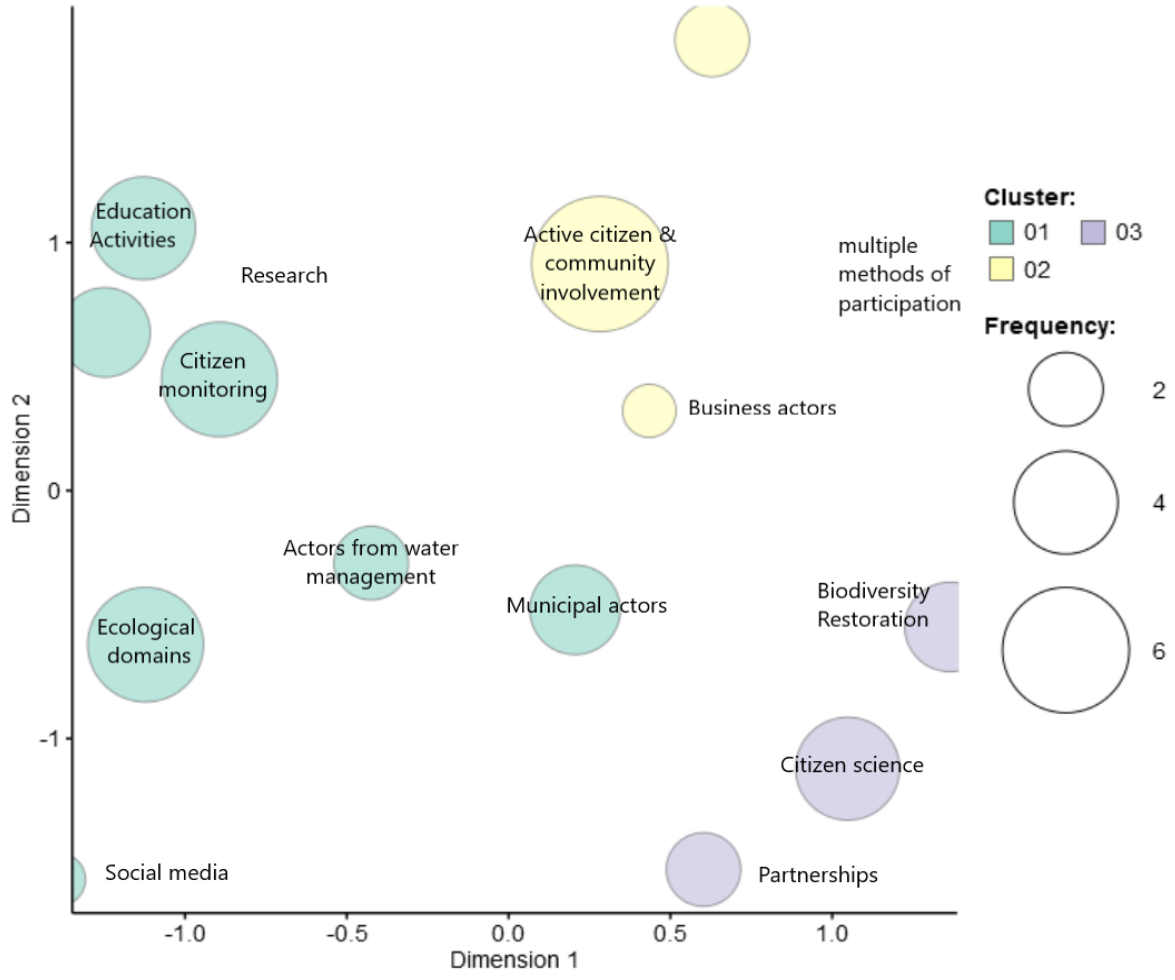

Figure 6-7 Multidimensional scaling qualitative commentaries that accompany modes of participation indicators

6.9 Discussion

6.9.1 Designing multifunctional ecological domains that impact health in cities

The research found that the type of ecological domain incorporated into the design of NBS could play an important role in disrupting the complex relationship between the determinants of ill health in cities. The analysis showed that external green buildings, parks, blue spaces and

derelict land with wild areas were moderate to strongly related to mortality. These findings concur with other studies (Mitchell and Popham, 2008; Hu et al., 2008; Mass et al., 2009) that suggest exposure to green or blue space (Wheeler et al., 2012) provided by NBS could influence the prevalence of heart or respiratory disease or all-cause mortality.

Unlike previous studies by Sempik (2010) and Mancebo (2016), this study did not find evidence of a relationship between mortality caused by heart or respiratory disease and community gardens or allotments, despite growing evidence of the role that urban food growing plays with encouraging agency with infrastructure). However, these types of NBS are typically implemented on a small scale (Bulthuis, 2020) and hence, the impact may not be observed at a population level despite evidence of the impact on the physical and mental health of an individual or across a community (Rutter et al., 2017). Similarly, green areas for water management, derelict spaces with wild areas and different types of greenspaces connected to grey infrastructure (often implemented on a street or neighbourhood scale) were not related to mortality due to heart or respiratory disease at a city scale despite emerging evidence in the literature (see Keynon et al., 2020; Venkataraman et al., 2019). Therefore, a key challenge for cities is how to design and implement NBS such as urban food growing programmes or SUDS that can provide salutogenic resources on a scale that impacts population health but also encourage people to reconnect with nature and stewardship of the urban fabric.

While scholars are critical of studies that examine the impact of interventions such as NBS on population health due to the issue of ecological fallacy and the inability to determine causality (Markevych et al., 2017), Rutter et al., (2017) argue that there is an urgent to develop a wider set of approaches that allow us to evaluate the impact of interventions such as NBS on health. In doing so, research agendas should also examine the role of different forms of governance, regulation or/and financial models play in the strength of the relationship between different types of NBS on health outcomes (both positive and negative). For example, the study found that the relationship between different types of ecological domains and mortality varied temporally with some types of green (such as large urban parks or botanic gardens) or blue space (such as wetlands or coastal NBS) related to mortality due to heart or respiratory or all-cause mortality in 2011, but not in 2016 or vice versa. Only two types of ecological domains

(green walls and derelict spaces) increased the effect size of the relationship between 2011 and 2016. However, questions remain about the reasons for the emergence of this variation in the strength of the relationship between the type of NBS and health. Rosol (2010) and Van der Jagt et al., (2016) suggest that the temporary nature of project-based funding or the implementation of austerity frameworks that lead to a reduction or withdrawal of funding for public health programmes may influence the temporal relationship between the types of NBS and health. A mismatch between the benefits imagined by cities and actual changes to population health may occur due to a lack of citizen engagement leading to conditions that cause poor health or health inequality to re-emerge.

This is further illustrated in Figure 6.2, which shows two clusters of NBS that aim to regulate urban processes: the first aims to facilitate climate adaption, urban regeneration and manage flood risk, while the second aims to provide the ecological infrastructure that improves the availability and quality of greenspace. However, specific conditions that encourage a high level of agency to enable improvements in health and well-being are excluded. This is perhaps explained by the lack of actors from public health involved in the design and deployment of NBS. Figure 6.7 shows that while governance of NBS involves an array of different actors, typically municipal actors, as well as private, public and the third sector, there is little evidence of the involvement of actors from the health sector. These findings concur with De Leeuw (2017), who suggested that health interventions such as NBS are primarily delivered by actors outside the health sector. Sneihotta et al., (2017) also argued that the exclusion of public health professionals that engage in multiple actions and practices to influence behaviour patterns and encourage agency might have a detrimental impact on the success of NBS.

However, the findings may also reflect a failure to consider the dynamic and emergent way in which interact NBS interact with social and economic factors in urban systems and how this, in turn, may influence agency with infrastructure and positively (or negatively) impact health and well-being. Cooper et al., (pending) suggest the influence of the prevalence of pre-existing structural conditions that influence unequal health and the exclusion of citizens (particularly disadvantaged groups) in the design, planning and implementation of NBS (Cooper et al.,,

pending) impedes agency. Consequently, the health and well-being benefits imagined by cities are not realised and inadvertently create environmental justice issues.

Similarly, differences in the scale of the intervention and analysis may also explain these results; co-occurrence analysis (see Figure 6.6) of qualitative commentaries provided by actors involved in these interventions suggests public health is not a primary consideration in the design and deployment of NBS by cities. Evidence suggests that the design of NBS is primarily influenced by urban redevelopment and regeneration. The research presented suggests that there may be two reasons to explain this; firstly, lack of explicit acknowledgement of the role that multifunctional NBS may play in disrupting processes that cause poor health and health inequality within the conceptual framework for NBS. This may lead to actors involved in designing and implementing NBS focusing on the direct economic benefits of these interventions. These findings concur with Rutter et al., (2017) and Salway and Green (2017) that interventions typically focus on individual-level outcomes rather than an upstream approach that considers how NBS could impact health at a population level. Secondly, a lack of knowledge or awareness of the role that NBS could play in addressing multiple societal challenges and an absence of empirical studies that report on the complex interrelationship and feedback (positive and negative) between different types of NBS and n health outcomes may also explain these results.

6.9.2 Gender differences in the relationship between NBS and health

Despite differences in the pattern of disease between men and women, studies that examine the relationship between mortality, gender, and different types of blue and green space are scarce (van Daalen et al., 2020). Due to a lack of data that relates to gendered health outcomes, the study examined the interrelationship between mortality by biological sex and the different types of ecological domains and the ecosystem services that they provide. The results are mixed; some types of ecological domain and ecosystem service were related to mortality in males and females, while others were differentiated by biological sex. Ecological domains such as external green walls, types of parks and seacoasts and ecosystems services that regulate climate (heat) and noise pollution were strongly related to mortality in males and females under

65. These results suggest that the deployment of NBS may modify the complex relationships between urban fabric, air quality, and heat exposure (including the effect of urban heat island effect), improving health outcomes.

Similarly, aesthetic appreciation of urban nature was also strongly related to biological sex-related mortality; these findings concur with existing research that suggests NBS mediate the impact of mental disorders and reduces the risk of CVD, stroke, and other diseases (see Table 6-6). Hence, NBS designed to provide opportunities for appreciation of art and aesthetic nature may help mediate the risk of all-cause mortality by building capacity and resilience in men and women. A recent opinion piece by Van Daalen et al., (2020) suggests that men and boys are more likely to experience mental health problems that increase the risk of mortality due to climate change due to the impact of excessive temperate on psychological exhaustion, aggressive behaviours and behavioural disorders (see Kumar Padhy et al., 2015). Hence, NBS that create services for aesthetic appreciation may be particularly important in cities that experience extreme temperatures, increasing prevalence of mental health disorders (including suicide) and/or high levels of criminal activity and antisocial behaviour. The study also found that ecosystem services that create opportunities for recreation, and physical and mental health were only related to mortality in males and not females. These findings support research by Richardson and Mitchell (2010) and Mitchell (2014), who found a relationship between lower mortality levels in males with increased greenspace in deprived areas. Thus, some types of ecological domains and the services they create may influence gendered differences in vulnerability to mental health problems in cities. Other types of ecological domains and ecosystem services were also differentiated by biological sex. NBS characterised by derelict and abandoned spaces with wild areas, riverine habitats and institution settings and ecosystems services provide medical resources, provide coastal protection, regulate air quality, increase the genetic diversity of habitats and provide 'other' types of cultural ecosystem services were moderate to strongly related to mortality in females but not males. These results suggest that some NBS may interrupt the complex interrelationship between sex-based differences in vulnerability, climate and adverse health by disrupting the processes of urban heat island, air pollution and by providing opportunities to build capacity through recreation and exercise.

However, Sultana (2014) suggests that differences in how climate change is experienced and acted upon by men and women is influenced by the intersectionality of social differences through class, race, and ethnicity. Hence, differentiated relationships between services for recreation and mental and physical health may not be explained by the ecological domain or ecosystem service the NBS provides but may be explained by how socially and culturally gendered roles influence the perception, experience, and use of NBS.

6.10 Conclusion

This paper takes a novel approach to examining the role that different characteristics of NBS play in disrupting complex processes that lead to poor health and health inequality in cities. By focusing on the interaction between different characteristics of NBS, the study demonstrates the complex interrelationships that influence the dynamic relationship between NBS and public health. The evidence presented demonstrates that some types of ecological domains, such as external green buildings, parks, blue spaces and derelict land with wild areas provided by NBS have the potential to prevent mortality. However, this study did not find any evidence of a relationship between health and types of NBS delivered on a small scale, such as community gardens or SUDS. In contrast, evidence of a relationship between different types of ecosystem services and health is mixed; services that regulate the ill-health effects of heat and poor air quality are related to biological sex-linked health outcomes. Therefore, a key challenge for cities is how to design and implement small-scale interventions such as urban food growing programmes in a way that impacts societal health by reducing the risk factors associated with NCDs.

Although complex systems approaches can be fraught with risk and uncertainty due to non-linear cause and effect or disproportionate impact of the intervention on the whole system (McGill et al., 2021), this study recommends that a systems approach is taken to designing NBS for health in cities. Failure to do so could inadvertently lead to climate injustice, particularly in cities with growing young populations or stagnating cities with increasing numbers of elderly vulnerable to the ill-health effects of extreme temperatures. These communities not only have poor access to salutogenic resources but are also the least likely to

have connections to help them address the cumulative effects of climate change that change socio-economic and cultural determinants of health. However, further research is required to understand the complex interactions that take place within cities as complex adaptive socio-ecological systems, the impact of rapidly changing physical environments due to urbanisation and climate change, and the role that NBS can play in influencing human well-being by facilitating agency and disrupting the relationship between the built environment and determinants of poor health.

7 Discussion and conclusions

This thesis aims to examine how the concept of Nature-based Solutions (NBS) relates to concepts that underpin the quality of life by unpacking the interconnected and dynamic relationship between the management and governance of NBS, socio-economic and socio-political factors at a macro and mesoscale. To achieve this aim four research objectives were outlined in the introductory chapter (Chapter 1) as follows:

- To unpack relationship between NBS and QoL by adopting an innovative methodology that draws on different sources of knowledge and methods of analysis to allow the pathways that influence interaction between these complex phenomena to emerge.
- To explore how the pattern of distribution of NBS relates to the pattern of uneven development in different regions and cities of urban Europe and the influence on QoL.
- To advance understandings of how the relationship between nature conservation paradigms that underpin NBS, and different modes of governance, participation and citizen involvement have evolved over time and in turn, how the patterns that emerge relate to QoL and environmental injustice.
- To explore how the impact that different types of ecological domains and ecosystems services provided by NBS relate to population health focusing on mortality related to respiratory and heart disease and all-cause mortality, including the influence of gender.

To respond to these objectives the final chapter is structured as follows. The contribution of the thesis to conceptual understandings of the relationship between QoL and NBS (Chapter 1) is discussed in section 7.1 followed by a discussion of the methodological contribution (Chapter 2) that the thesis makes in 7.2. This is followed by a discussion of the key findings from each empirical research (Chapters 4-6) which examines the extent to which the research questions have been met and what further questions remain. Then, section 7.6 sets out the main conclusions from the study, followed by a discussion of the study's limitations and questions for further research.

7.1 Key research findings

7.1.1 The relationship between the conceptual framework for NBS and different social and economic factors that influence QoL

The premise underlying NBS is that by joining up action on climate adaptation with action to address other challenges (such as water management) cities can manage, create, or restore ecosystems to help stimulate green recovery and improve QoL of urban inhabitants. However, in developing the definition of NBS researchers, policymakers and those implementing NBS adopt normative assumptions about the capacity of NBS to disrupt deeply entrenched inequalities in cities and fail to acknowledge the complexity of interactions between different factors that influence the design, governance and management of NBS and different social and economic determinants that influence QoL and poor health and in turn, the consequences for environmental injustice. The research advances our understanding of the relationship between QoL and NBS by conceptualising QoL as a networked relationship between different socio-economic conditions, socio-cultural and socio-political processes, the urban fabric (including green and blue space provided by NBS and the ability and opportunity of urban inhabitants to access those resources through the governance and management of NBS (Figure 7.1). This conceptualisation provided a framework to unpick the interactions that occur between attributes that influence the deployment of NBS, in particular, the nexus between governance-participation-citizen and how they positively or negatively influence the pattern of distribution of resources provided by NBS (such as ecological domains and ecosystems services) and the development of capabilities that aid climate adaptation and improve QoL or whether these conditions create issues of distributional, participatory or recognition injustice.

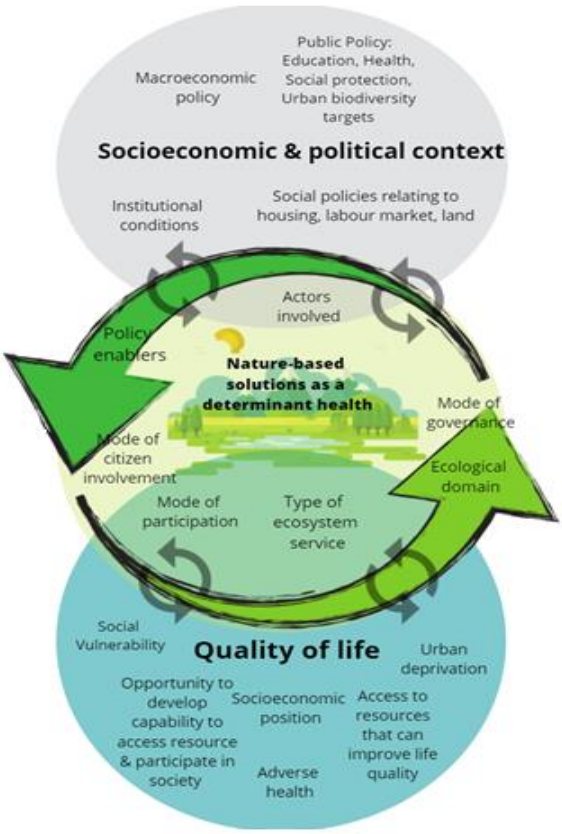

Figure 7-1 *Conceptual Relationship between different macro socio-economic and political contexts, the different characteristics of NBS and QoL*

The theoretical framework advances understanding of the relationship between NBS, QoL and macro socio-economic and socio-political contexts that shape the allocation of resources (such as different types of green and blue space or the ecosystems services they provide) in cities deploying these solutions.

Despite criticism that NBS is a concept of frames that is vague and ill-defined, actors from across policy, practice and research continue to emphasise the potential of these interventions to deliver win-win outcomes for sustainability. Given the level of hope invested in NBS and the continued focus on win-win narratives (Chapter 2) and limited availability of high-quality data across different types of NBS, scales, socio-economic and socio-cultural contexts (Chapter 3), it is vital that research into the effectiveness of these interventions take a holistic, systematic approach to critically appraise how (or if) these solutions can achieve these

aspirations and if the evidence does not support their claims, ask how we can evolve how NBS are managed and governed to improve the QoL of those most vulnerable to the ill-health effects of climate change and urbanisation. Hence, this thesis adopted a hybrid research design and sophisticated multi-method approach to unravel the complex interrelationships between different characteristics, material, and social phenomena and in turn, the QoL of urban inhabitants. In so doing, the thesis adopted a form of methodological eclecticism that crossed different research paradigms so that different methods and sources of data could be analysed from different perspectives allowing the complex patterns and structural relationships between NBS and different socio-economic characteristics at a macro scale (Chapter 4) and their influence on the frames that underpin the implementation of NBS at a city-scale and the consequences for QoL and environmental justice (Chapter 5) to be revealed. Given the limitations of the data and scale of the analysis, a reflective approach was adopted to data analysis and interpretation to check the representativeness and meaning of the research findings. To aid in the triangulation of the findings, the thesis rejected the 'incompatibility' thesis and challenged the notion of the quantitative-qualitative divide by integrating statistical analysis of the relationship between different types of NBS, the ecosystems services that they create and health with quantitative text analysis of qualitative commentaries published in the Urban Nature Atlas. One of the main limitations of the thesis is the lack of cross-case analysis of the relationship between NBS and QoL at a neighbourhood scale across different cities due to limited available data. To address this gap, further research should be undertaken utilising population-based administrative data that is available in cohort studies to examine the role that different types of NBS play in influencing QoL and specific health outcomes.

7.1.2 How does the pattern of distribution of NBS relate to the pattern of uneven development in different regions and cities of urban Europe and how does this influence QoL?

Chapter 4 demonstrates that the distribution of NBS follows a social gradient that mirrors the pattern of uneven development across urban Europe with multifunctional NBS that are designed to create different types of ecological domains and an array of ecosystems services primarily located among frontier economies leading to the unfair distribution of resources that could improve QoL, especially in parts of Eastern and Southern Europe where severe

deprivation is prevalent. Similarly, the distribution of financial resources, particularly European investment also follows a similar trend whereby post-industrial cities compete against transition economies to secure investment for urban regeneration under the guise of urban greening in a quest to rebrand and upskill to attract cultural capital to allow these cities to compete on a global scale once again. This results in a form of state rescaling (Keating, 2021) where the divide between frontier and transition economies worsens as transition economies with higher levels of those at risk of poverty or the social exclusion or severe deprivation receive lower levels of investment for NBS. Consequently, transition economies co-produce fewer resources or services that could help to improve the QoL of urban inhabitants leading to frontier economies experiencing a form of enviro-economic privilege driven by inter-regional competitiveness and tournament financing (Peck, 2012).

Ironically, European policy leads to further economic divergence rather than convergence as marginalised or shrinking cities miss opportunities to secure investment reinforcing patterns of stagnation and uneven development among transition economies and reinforces that dichotomous relationship between people and nature as NBS are deployed by frontier economies to create 'passive' welfare measures and transfer of responsibilities traditionally managed by the state to the community. Exploratory data analysis conducted in Chapter 4 showed these findings were reflected in the number of NBS to help tackle inequalities in cities, that is only 2% of NBS with the remainder distributed based on income and growth in more affluent cities with a strong innovation capacity. Results presented in Chapter 4 demonstrated that less than 25% of NBS related to new housing or neighbourhood regeneration (despite the prevalence of a gradient in the quality of housing that stretches west to east and north to south in Europe) where citizens lacked access to adequate resources to meet the basic needs for an adequate QoL due to severe deprivation. Likewise, other factors that relate to QoL such as the decline in the age of urban populations in peripheral cities or the occurrence of heat-related environmental burdens that caused ill-health or mortality were also unrelated to the distribution of NBS.

Despite the dominance of win-win narratives across the discourse, Chapter 4 highlighted that the distribution of NBS across urban Europe is spatially and socially selective, rarely targeting

deprived communities or disadvantaged residents to improve their QoL. Lack of integration of NBS across different policies particularly economic convergency policy by the European Commission combined with an emphasis on financial gains and innovative potential of NBS has not only acted as a barrier to equitable distribution of the NBS benefits of NBS creating issues of distributional injustice among transition economies and privileged frontier economies but also reinforced structural injustice as the resources, opportunities for education and skills development are concentrated in more advantaged regions of Europe.

7.1.3 Influence of nature conservation framings on the interaction between governance, participation, and citizen engagement and consequences for environmental injustice

The research presented in Chapter 5 examined the influence of changing nature conservation paradigms that underpin the conceptual development of NBS on the nexus between governance, participation, and citizen involvement and how emerging patterns relate to factors that influence QoL in cities. Scholars claim (see Mace, 2014; Cohen-Shacham et al., 2016) that paradigms that underpin NBS have evolved to centre the benefits on nature and people to facilitate city-citizen interaction that enable broad participation and the equitable resources and opportunities that NBS claim to create. However, the research presented in Chapter 5 shows that NBS continue to be blighted by the domination of hegemonic framings and uneven power relations between city-citizen interactions hindering the 'potential' of these interventions to enable just transitions to sustainability. Together with evidence that the distribution of NBS does not relate to divergent and entrenched inequalities across urban Europe (Chapter 4), this thesis is one of the first studies to show scalar evidence of how the planning, design, management and implementation of NBS continue to be embroiled in neoliberal practices. If these issues are left unaddressed by researchers, policy makers and practitioners enacting and implementing these solutions, their implementation will not only risks reproduce or exacerbate inequalities that influence the determinants of ill-health but may also lead to maladaptation of groups (particularly children and the elderly) to climate change leading to environmental injustice.

7.1.4 Hegemonic narratives dominate NBS implementation

Mace (2014) suggested that before the late 2000's paradigms that underpinned early NBS reinforced the dichotomy between people and nature. Investigation of the pattern of clustering between governance, participation and citizen involvement of cases deployed between 1990 and 2009 (retrospectively classified as NBS by Naturvation) collaborates these claims. Evidence suggests that over 60% of cities implementing NBS are primarily driven by urban development goals that aim to transform the decaying urban infrastructure caused by the legacy of post-industrialism under the pretext of climate urbanism and new city-making paradigms. Similarly to other scholarship (Rosol et al., 2017, Long and Rice, 2019; Schuetze and Chelleri, 2016; Dangelico and Pontradolfo, 2015), this thesis finds that NBS implemented throughout the 1990s and 2000's were often used as an ecological modernisation strategy for urban regeneration to transform stagnating economies and enable them to market themselves. The research presented in Chapter 5 builds on these studies by illustrating the consequences for environmental justice; while NBS often adopted hybrid governance arrangements that fostered inclusivity among different groups of private-state actors they frequently lacked but lacked equity considerations leading to the exclusion of citizens and disadvantaged groups. These findings concur with studies by Walmsler et al., (2017) that suggest that citizens are often excluded from institutional processes that influence the management and governance of NBS. In contrast to this study, the findings suggest exclusionary 'politics of difference' (Young, 2011) lead to the misrecognition and oppression of urban inhabitants and disadvantaged groups. This not only denies these groups with opportunity to develop or exercise their capability to access resources that could help them improve their QoL but also risk maladaptation because of the domination of municipal actors. Furthermore, different indicators related to social and economic determinants that influence poor health were largely unrelated to the distribution of different clusters of NBS with similar characteristics reinforcing the human-nature dichotomy leading to the maldistribution of environmental goods.

Despite the lack of consideration of equity in institutional and participatory processes and how these influence different social and economic determinants of ill-health, the findings also revealed that citizen science plays an important role throughout the 1990s and 2000s. Scholars

argue (Cardenas et al., 2021; Schuttler et al., 2018) citizen participation through citizen science can play an important role in transforming societal attitudes to sustainability, enhancing social learning and civic engagement helping to improve health and well-being (Ceccaroni et al., 2021). However, the findings presented in Chapter 5 suggest that citizen science has been deployed to achieve functional rather than transformative goals with private actors offering tokenistic opportunities to engage with NBS to improve their marketability, diffuse concerns or opposition to urban development or environmental impacts, r achieve financial efficiencies in data collection. Thus, opportunities to influence to help citizens develop capabilities to access resources or develop skills that may support adaptation through engagement with citizen science are missed.

The research presented in Chapter 5 also found that NBS deployed throughout the 1990s and 2000s were also influenced by fiscal drivers to secure foreign investment to regenerate post-industrial or shrinking cities, targeting areas perceived as 'wastelands' into large urban parks. These findings concur with studies by Kronenberg (2015) and Hasse et al., (2019) which suggest investment in urban green projects in post-socialist cities has been driven by a market-orientated and neoliberal approach to restructuring. In contrast to these studies, the analysis shows that whilst the distribution of NBS in these cities is related to factors that influence social vulnerability, urban deprivation and poor health, hegemonic framings dominate leading to the uneven distribution of resources that could help to improve QoL and participatory injustice that in turn, denies urban inhabitants the opportunities to develop the capacity to access these resources.

Of the three clusters of NBS that emerged from analysis of cases that were implemented during the 1990s' and 2000's only one group, governed by community actors that through the creation of allotments or community gardens that they envisage will benefit people (particularly those disadvantaged) and improve biodiversity. However, whilst this group of NBS attempt to foster inclusivity by adopting an array of participatory methods, a lack of consideration of how to design participatory approaches for disadvantaged and marginalised groups leads to their exclusion. These findings concur with studies by Certoma and Tornaghi (2019) and Crossan et al., (2016) that while these projects envisage that they will to alleviate food insecurity and

social connectedness through progressive forms of political practice that help, but they can also be sites where class-produced natures (Domene and Sauri, 2007) can emerge mediated by the cultural elite with higher levels of educational attainment and knowledge of nature (Exner and Schutzenberger, 2018).

7.1.5 Normative framings post 2010 hindering just transformations in cities

Mace (2014) suggests that in the early 2010's the nature conservation paradigm that underpins NBS evolves from one that externalises nature (that dominated in the 1990's and 2000's) to one in which the benefits of NBS are equally for people and nature. However, analysis presented in Chapter 5 of the thesis shows that while different institutional conditions become more collaborative with increasingly involving citizens, framings that dichotomize nature that prioritizes urban green agendas of private and state actors continue to dominate. Consequently, governance, participation, and citizen engagement interactions are inattentive to what Honneth and Fraser (2003) describe as the 'politics of redistribution and recognition'. If addressed, they could help to alleviate the upstream determinants of poor health and reduce the vulnerability of disadvantaged groups to the ill-health effects of climate change and urbanisation urbanization.

Post-2010, over 50% of cities deploy NBS that are characterised by coalitions of private and public sector actors to co-create multifunctional blue-green infrastructure that involves citizens in the oversight and management. Toxopeus et al., (2020) suggest hybrid governance strengthens justice outcomes of NBS by explicitly including citizen involvement and participatory governance, but these results challenge those claims. The results indicate that the persistent enactment of human-nature dichotomic framings by private and public sector actors that govern NBS, even when these processes are collaborative, leads to distributive, participatory, recognition injustice and injustice as capability. The evidence suggests that powerful actors deploying these solutions frequently fail to take account of prevailing social and economic conditions that lead to urban deprivation, social vulnerability, and poor health when planning and designing these interventions. These findings are similar to other studies (e.g. Rosol et al., 2017; Whitten, 2019; Long and Rice, 2019) that found hegemonic narratives

such as the pursuit of lucrative European investment funds, rebranding of cities, or implementation of austerity measures can be key drivers of urban greening programmes. Consequently, urban inhabitants especially those vulnerable to the effects of urbanisation or climate change are denied the opportunity to access resources or develop capacities that could improve QoL and aid climate adaptation.

Similarly, there is little evidence that framings that underpin the deployment of NBS by the community, private company, or state-led actors have evolved to equally benefit nature and society nor do they relate to different social or economic conditions related to urban deprivation, social vulnerability, or poor health. The research presented in chapter 5 also shows that those NBS still in planning at the time of collection were also driven by urban regeneration to co-create ecosystems services for people that provide urban inhabitants with opportunities for recreation or to improve, physical and mental health but lack evidence of services being created to support urban biodiversity agendas. These NBS aim to foster inclusivity by involving community actors in the consultation, co-planning, or crowdfunding phase of these interventions, but lack of evidence of a relationship with urban deprivation could suggest that these interventions are not to be located where urban inhabitants lack access to greenspace causing distributional injustice and reinforcing existing inequalities. In the fourth cluster, NBS is governed by the private sector, civic society, or state actors but jointly implemented with the involvement of business, research institutions, local government, or NGOs. Although institutional and management processes are led by and involve different actors, the needs of citizens seem largely unconsidered with tokenistic opportunities for stakeholder engagement offered through interviews or completion of questionnaires which could lead to issues of procedural and recognitional injustice.

7.1.6 Evidence of impact of NBS on health at a city-scale

Despite lack of evidence that QoL is a factor that is considered in the distribution of resources and the design of governance processes and management practices, the research presented in Chapter 6 demonstrates that external green buildings, parks, blue spaces, and derelict land with wild areas are moderate to strongly related to mortality after adjusting for confounding with

the size of the effect varying by mortality indicator. These findings concur with other studies (Mitchell and Popham, 2008; Hu et al., 2008; Mass et al., 2009; Wheeler et al., 2012) that suggest exposure to green or blue space provided by NBS could influence the prevalence of heart or respiratory disease or all-cause mortality. In contrast, different types of community gardens or allotments were not associated with mortality caused by heart or respiratory disease. These results were surprising since research by Sempik (2010) and Mancebo (2016) suggests that urban food growing plays a role in encouraging agency with infrastructure. Similarly, other street or neighbourhood scale NBS such as green areas for water management, derelict spaces with wild areas, and different types of greenspaces connected to grey infrastructure were also unrelated to mortality due to heart or respiratory disease at a population level despite emerging evidence in the literature (see Venkataramanan et al., 2019). However, the reason for the lack of evidence at a population level may be explained by the scale of implementation (Bulthuis, 2020), leading to impact not being observed even though improvements in health may be observed at a local level. Thus, a key challenge for cities is how too upscale these types of NBS, especially design urban food growing programs on a scale that provide salutogenic resources to those that lack access to green space and encourage people to reconnect and take ownership of the urban fabric more broadly.

The study also found that the relationship between different types of ecological domains and health can vary temporarily, perhaps reflecting a reduction or withdrawal of public health interventions whose funding may be project-based (Rosol, 2010; Van der Jagt et al., 2016). Triangulation of the results with qualitative commentaries published in the UNA suggests these interventions are primarily designed to help cities adapt to climate change, regenerate urban areas, manage flood risk, or increase green space availability, but lack consideration of the role these NBS could play influencing poor health. These findings are consistent with studies by De Leeuw (2017) and Sneihotta et al., (2017), who suggest that actors often deliver health interventions outside of the public health sector leading to a lack of consideration of how to design interventions that change patterns of behaviour. Together with the research presented in Chapter 5, the findings suggest that power actors imagine that the creation of NBS will create a passive form of welfare driven by the retraction of the welfare state. The exclusion of actors

from the public health sector not only leads to recognition injustice for these actors but misses opportunities to design interventions that could influence the upstream determinants of ill-health and prevent maladaptation.

In addition to questions about the relationship between QoL and NBS, Chapter 6 of the thesis also examined the relationship between population health and different types of ecological domain, ecosystem service and all-cause mortality by gender. Despite differences in the pattern of disease between men and women, studies that examine the relationship between mortality, gender, and different types of blue and green space are scare (van Daalen et al., 2020). Analysis of the relationship between mortality by gender and the different kinds of ecological domain and the ecosystems services revealed mixed results. Some types of ecological domain and ecosystem service were related to both mortality in men and women, while others were differentiated by gender. Ecological domains such as external green walls, types of park, and sea coasts, and ecosystems services that regulate climate (heat) and noise pollution were strongly related to mortality in men and women under 65 years, suggesting the deployment of NBS may modify complex relationships between urban fabric, air quality, heat exposure (including the effect of urban heat island effect) improving health outcomes for the risk of heart and respiratory diseases.

The research presented in Chapter 6 also found that aesthetic appreciation of urban nature was also strongly related to gender-related mortality; these findings concur with research that suggests NBS mediate the impact of mental disorders and reduces the risk of CVD, stroke, and other diseases. A recent study by Van Daalen et al., (2020) suggests that men and boys are more likely to experience mental health problems that increase the risk of mortality due to climate change. Excessive temperate can cause psychological exhaustion, aggressive behaviours and behavioural disorders (see review by Padhy et al., 2015). Although there is a lack of evidence that NBS has been targeted in NBS in cities that experience extreme temperatures or a divergent population structure (Chapter 4) so far, the findings from the research presented in this thesis suggest that NBS create services for aesthetic appreciation are important for cities that with divergent population structure (Chapter 4), increasing prevalence

of mental health disorders (including suicide) and/or high levels of criminal activity and antisocial behaviour.

The study also found that ecosystems services that create opportunities for recreation physical and mental health were only related to mortality in men and not women. These findings concur with research by Richardson and Mitchell (2010) and Mitchell (2014), who found a relationship between lower levels of mortality in men with increased greenspace in deprived areas. This could suggest that some types of ecological domains and the services that they create may influence gendered differences in vulnerability to mental health problems in cities. Other types of ecological domain and ecosystem service were also differentiated by gender. NBS characterised by derelict and abandoned spaces with wild areas, riverine habitats, and institution settings and ecosystems services for providing medical resources, coastal protection, regulating air quality, increasing the genetic diversity of habitats, and providing 'other' types of cultural ecosystem service were moderate to strongly related to mortality in women, not men.

7.2 Principal conclusions from research

To examine the relationship between NBS and QoL, this thesis conceptualised QoL as a networked relationship between different socio-economic conditions, socio-cultural and socio-political processes, the urban fabric (including green and blue space provided by NBS and the ability and opportunity of urban inhabitants to access those resources through the governance and management of NBS. By examining the interactions between different characteristics that influence the practice and implementation of NBS with different social and economic determinants of ill-health, results presented in this thesis show that the distribution of NBS rarely takes account of entrenched, social, and economic conditions that adversely affect urban QoL (Chapter 4) despite the repeated reference to the importance of NBS for good QoL in the scientific literature. Despite the persistence of win-win narrative across the discourse and claims that paradigms that underpin the framing of NBS have evolved, this thesis finds little evidence that factors such as the increasing aging and growing young population, limited availability of quality housing with access to salutogentic resources to support climate adaptation, widening of social and health inequalities, and loss of urban biodiversity, and the

dynamic way in which each of these factors interacts to influence QoL do not influence the enactment and deployment of NBS in many European cities despite the urgency of the climate challenge and the imperative for cities to transition to sustainability.

The findings from this thesis also show that while the pathways, at a macro, state and meso level are deeply entwined and contested, often hindering the potential of NBS to positively influence the upstream social and economic determinants of ill-health, and unjustly distributing their benefits. Given the stakes at play and the hope invested in NBS, the findings presented in this thesis highlight the importance of adopting a multi-method approach but predominantly quantitative research design that is relational and reflective to unravel the complex, sometimes hidden connections and negative feedback loops within the data. It is only by doing so that research can unpack how interactions between different socio-economic and socio-political contexts influence the design, governance, and management of NBS influence QoL and provide evidence to challenge the persistence inequitable and hegemonic goals underpin to challenge win-win imaginaries for NBS that are common across the discourse.

Exploratory data analysis and thematic mapping presented in Chapter 4 shows how the distribution of multifunctional NBS that could provide resources to improve QoL are primarily distributed among privileged frontier western economies influenced by the political economy of transnational institutions and knowledge politics between the frontier and transnational economies. These trends are partly explained by repeated inattention to the complex intersectional relationship between pre-existing and historical urban conditions that influence the social determinants of poor health in determining the priorities for investment in NBS, but also the role of state rescaling (Keating, 2021). Lack of integration of NBS across European policy and a drive for economic convergence in the wake of the post-socialist era and retrenchment of the welfare state coupled with hegemonic narratives that dominate the discourse has arguably to uneven distribution of the resources that could improve QoL among frontier economies not only acting as a barrier to the just and equitable distribution of resources but also creating issues of intraregional distributional injustice. Ironically, instead of European policy improving QoL, state rescaling reinforces pre-existing inequalities creating issues of

structural injustice as the resources and opportunities for education and skills created by NBS development are concentrated in more advantaged regions of Europe.

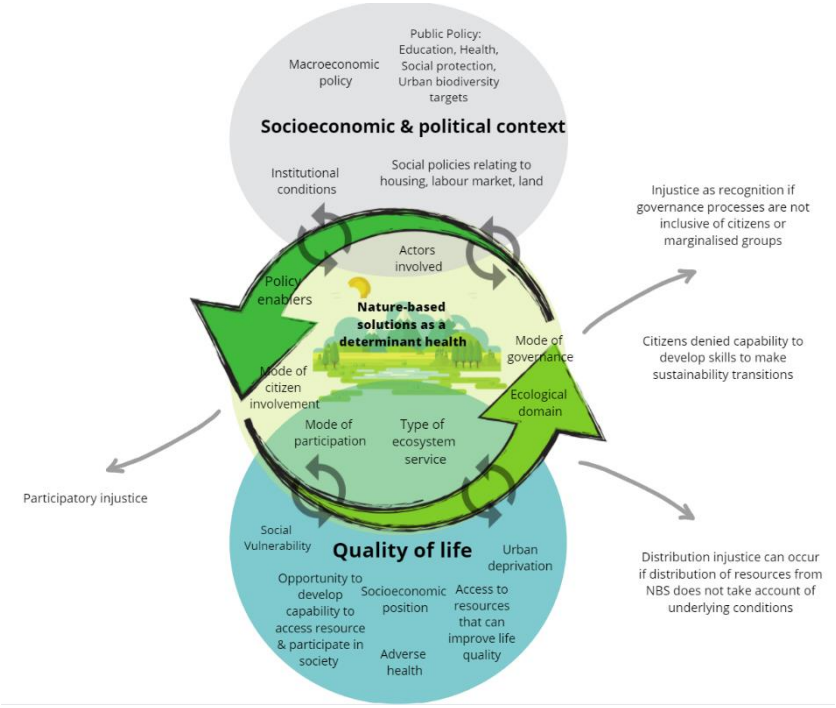

Figure 7-2 ***Relationship between socio-political contexts that influence social and health inequality, the differing characteristics of NBS and QoL***

To further unpack the influence of socio-economic and socio-political contexts at a mesoscale, Chapter 5 examined the interrelationship between governance, participation, and citizen involvement and in turn, how the patterns that emerge have changed in response to paradigm shifts from one which externalises nature (1990 to late 2000s) to one which aims to deliver equal benefits for both society and nature (2010 onwards) influence the distribution of benefits that could improve QoL. Thus, the thesis provides one of the first empirical cross-case comparisons of the role of shifting nature conservation paradigms on the narratives that underpin the implementation of NBS and the consequences for QoL and environmental justice. The findings show that normative frames and hegemonic narratives that dichotomise the relationship between people and nature continue to dominate NBS despite an apparent

evolution in the paradigm that underpins the concept and consequently, city-citizen interactions are devoid of social justice or equity considerations leading to the emergence of different forms of environmental justice as. Furthermore, few cities take the opportunity to design NBS that influence the prevailing structure and condition of housing, population-age structure of cities or the prevalence of severe deprivation and risk of poverty to improve QoL by influencing the upstream social and economic determinants of ill-health. Consequently, the potential of NBS to achieve their potential to deliver just transformations to sustainability by confronting these challenges is missed as these interventions become misdirected and embroiled in framings that dichotomise people and nature leading to distributive injustice.

The study also found that dichotomous framings lead to inherent biases in the governance NBS negatively impacting participatory processes from the design phase through to monitoring and evaluation of NBS. Furthermore, few NBS engage with actors that could aid understanding of the prevailing social and economic conditions that influence urban deprivation or social vulnerability, or design of interventions that could help alleviate the upstream conditions of poor health, leading to recognition injustice for those actors. There may be two reasons for this; firstly, power and politics of who benefits from NBS and why continue, not only influences the allocation of resources at a macro-level but neoliberal urban restructuring driven by austerity and the retrenchment of the welfare state also impact the implementation of NBS at a meso-level. These findings reflect the harsh realities of the politics of transformation that is driven by austerity urbanism (Peck, 2012, 2014); like frontier and transition economies, different groups of actors compete for ever-dwindling sources of finance at a municipal level influenced by the persistence of win-win 'nature for growth' narratives among state-private and public-private partnerships. Secondly, lack of awareness of paradigm shifts in nature conservation coupled with limited knowledge and understanding of the ‘people and nature’ paradigm among the actors implementing state-private or public-private partnerships results in the potential of NBS being blighted by the pursuit of hegemonic narratives.

Despite the disparity between the distribution of NBS and different social and economic conditions that influence poor health and the persistence of hegemonic narratives across the implementation of NBS, the study found that different types of ecological domain and

ecosystem service are moderate to strongly related to different mortality indicators based on interpretation of size effect by Cohen (1988). These findings concur with other studies (Mitchell and Popham, 2008; Hu et al., 2008; Mass et al., 2009) which suggest exposure to green or blue space (Wheeler et al., 2012) provided by NBS could influence the prevalence of heart or respiratory disease or all-cause mortality, particularly in those communities that are exposed to greater risk of ill-health effects caused by climate change due to limited access to salutogenic resources. In addition, evidence of a relationship between different types of ecosystems services, particularly regulatory and cultural with all-cause mortality and all-cause mortality by gender indicates the services provided by these interventions disrupt the complex interrelationship between gendered differences in vulnerability, climate, and adverse health, particularly those that regulate the health effects of urban heat island or air pollution and provide opportunities to build capacity through recreation and exercise. However, Sultana (2014) suggests that differences in how climate change is experienced and acted upon by men and women are influenced by the intersectionality of social difference through class, race, ethnicity, etc. Hence, differentiated relationships between services for recreation, mental and physical health may not be explained by the ecological domain or ecosystem service the NBS provides but may be explained by how socially and culturally gendered roles influence the perception, experience, and use of NBS.

Together the research presented in each of the empirical chapters suggests that the dynamic and emergent ways in different socio-economic and socio-political contexts interact with NBS at both a macro and mesoscale and the consequences for QoL and environmental injustice. Furthermore, lack of consideration of the complex interactions between different material and social phenomena with socio-political conditions leads to missed opportunities to influence the upstream determinants and improve QoL of city dwellers. These findings with Rutter et al., (2017) and Salway and Green (2017) suggest a complex systems approach is rarely taken to framing or designing public health interventions but tends to focus on linear models and individualistic interventions. Hence, while paying attention to the critiques of NBS (Chapter 2) and the empirical research from Chapter 4 to 6, the thesis proposed to redefine the concept of NBS to move away from dichotomous thinking and hegemonic narratives to centre the

benefits of NBS equally among people that need the resources these solutions the most and the advancement of urban biodiversity goals. This thesis, therefore, redefines NBS as 'actions that sustainability use, manage or improve the biodiversity of natural or socio-cultural, modified, degraded or man-made ecosystems to help cities adapt to help those most vulnerable to the effects of urbanisation and climate change improve their life quality, but deliver equal benefits for people and biodiversity through just and inclusive citizen engagement'. This definition aims to encourage policymakers, researchers, and practitioners to design NBS that deliver improve biodiversity and provide resources for people that could mediate the upstream causes of ill-health and social inequality by targeting NBS in regions, cities or neighbourhoods were low-income and deprived communities are at most risk from the ill-health effects of climate change.

7.3 Limitations

The research from this study sought to advance conceptual understandings of the relationship between NBS and QoL by examining the influence of divergent social and economic conditions and evolving nature conservation paradigms on the distribution of different attributes of NBS and, in turn, their relationship with factors that relate to poor health across different scales. However, the availability of good quality spatial data that delineated the boundary of each NBS and the lack of availability of comparable social, economic and health indicators at neighbourhood scale limited the scope of this study. There are two reasons for this; firstly, primary data on the different characteristics of NBS (Chapter 3) was collected prior to my appointment to the Naturvation programme and thus, there was no opportunity to influence or improve the research design of the work package that the PhD was part of and limited time available to research each case of NBS meant insufficient data was collected to accurately the spatial boundary of NBS. Secondly, the thesis drew on Secondary data published in the Urban Audit, a dataset that consists of quality of life (QoL) indicators for cities published by Eurostat. This dataset is one of the few QoL datasets available on a pan-European basis that includes: demographic, social, economic, environmental, training/education, and (for a limited number) health indicators for each city included in the city and plays a central role in capturing the everyday realities of poverty and urban deprivation but lacks data on indicators that relate to

trends in disease or subjective well-being. Another limitation of the study associated with the use of secondary data published by the Urban Audit was the granularity of available data. Data for each indicator was published was based on three spatial units: Functional Urban Area, Greater City and City, but varied by spatial unit, reference year, and city since submission of Urban Audit indicators by different member states was not mandatory. In some states, indicators are based on modelled estimates reducing their reliability of the data or there were differences in the approach taken to delineating administrative boundaries making the comparison of QoL between cities more challenging.

In addition to limitations with the quality of the secondary data, the analysis conducted in the study was also constrained by lack of a comparable set of area level indicators where NBS had been implemented and hence it was not possible to conduct a cross-city comparison of the relationship between different types of NBS at a neighbourhood level. Thus, analysis of the relationship between NBS and QoL was limited to macro, state and mesoscale. Similarly, analysis of the relationship between different types of NBS and health was limited to analysis of the relationship between different classifications of mortality. Across European cities, there is a lack of good quality data that enables the analysis of the complex relationship between different types of NBS and the benefits they provide and different types of health conditions. This is further hindered by a lack of access to sufficient monitoring data that allows the causal relationship between the NBS and health to be established.

Another limitation of the research is the level of aggregation embedded in macro-region and city-scale analysis (Chapter 4). The analyses mask the spatial variation in both the distribution of the characteristics of NBS and inequality across different macro-regions, states, and within and between cities. Unfortunately, it became apparent in the early stage of the research that individual or area-level indicators for QoL across European cities were not available preventing inter-city comparison of the impact of NBS on neighbourhood or individual QoL. In the phase of the research, these gaps will be addressed this gap by developing a cross-city research design that will combine small-area indicators of QoL with subjective well-being data to examine the influence of specific types of NBS on public health problems (such as mental health).

7.4 Recommendations for future research

It has become apparent over the course of the research that the distribution of NBS is influenced by different socio-political contexts that cannot be easily tackled (Clement, 2021; Young, 2017); the climate crisis and biodiversity loss are rooted in socio-economic structures and institutional conditions that continue to reinforce the dichotomous relationship between nature and people. This study shows that despite alleged reframing of the nature conservation paradigms that underpin NBS, the supposed transformative potential of these solutions continues to be blighted by hegemonic narratives and the prevailing power structures that are evident across state-private and private-public partnerships that lead to a focus on short-term environmental goals and disjointed decision making (Seddon et al., 2020). To address these problems, further research is required to explore how the conceptualization of NBS can be refocused to ensure the benefits that they create are centred on the needs of communities vulnerable to the effects of climate change and address urban biodiversity challenges without reproducing structural inequalities or issues of environmental injustice.

Further work to reconceptualize NBS should examine the relationship between relational QoL and these interventions. In this study, the evaluation of conceptual linkages between NBS and QoL assessments were solely based on quantitative measures due to data limitations, but Michalos (2014) and Land and Michalos (2015) argue that QoL assessment should be based on objective and subjective indicators (Chapter 2). Thus, in the next phase of the research work will be undertaken to develop a conceptualisation of QoL to encompass the influence that nature has on life quality (see Schroter et al., 2020; Chan et al., 2016) and explore how this may be used to refine the conceptual framework of NBS to focus on equal benefits for people and nature. To help understand how NBS influences the relational quality of life within and between cities, a cross-city study of the influence that different types of NBS and the ecosystems services they co-create impact on relational notions of QoL at neighbourhood scale is required. This is no small task; hence the research will focus on the role of street or neighbourhood scale interventions in disadvantaged communities with little access to NBS or where the quality of existing greenspace has become degraded. Initially, an approach will be piloted that allows the values that different groups attach to these spaces and how they influence

the relational QoL to be quantified using a hybrid research design. This will encompass primary data collection through participatory action research followed by relational quantitative analysis of relational, subjective, and objective QoL indicators.

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