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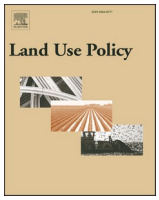

Distribution of Nature-based Solutions in cities across Europe

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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 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.

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 (Eiseman, 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 & 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; Mitchell et al., 2015).

The stark inequalities of access to high quality greenspace have been

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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 (Mitchell and Popham, 2008; Mitchell et al., 2015), Wolch et al. (2014) argue that the distribution of good quality greenspace provided by NBS is often influenced by the economic and social characteristics of a neighbourhood with disadvantaged areas receiving the poorest quality greenspace. Richardson et al. (2013) argue that the persistent and further deepening of inequalities in access to green and blue space provided by NBS risks exacerbating 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) argues this approach not only risks triggering marketisation and gentrification but can deepen 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 shown in Table 1 relates to underlying social and economic conditions that influence QoL across Europe using data published in the Urban Nature Atlas (UNA) (www.una.city) (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 characteristics of NBS relates to the distribution of structural inequalities across Europe.

Table 1
Indicators published in the Urban Nature Atlas for each of the cities included in the Naturvation project (adapted from Almassy et al. 2017).

Urban Nature Atlas Data Variables	
General information	Grid reference co-ordinates to denote the spatial location of the intervention.
Key characteristics	
Ecological domains	Frequency counts 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	Frequency counts that represent the number of each type of ecosystem service supplied by each NBS divided into provisional, regulatory, habitat supporting and cultural ecosystems services. Each group has a subset of services.
Governance	Frequency counts that represent the number of each type of governance used for NBS and different non-governmental actors leading governance.
Key Actors	Frequency counts that represent the number of each different type of key actors and stakeholders involved in the planning and implementation of NBS
Participation	Frequency counts 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	Frequency counts 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.
Funding	Frequency counts of the number of NBS in each total cost category.
Innovation	Frequency counts that represent the different forms of urban innovation that were applied in each NBS categorised into social or technical innovation.
Scale	Frequency counts that represent the scale of the intervention: macro (region), meso (city), micro (neighbourhood) or submicro (street scale).

2. Understanding the role of Nature-based Solutions in the transformation of quality of life in cities

2.1. What are Nature-based Solutions?

According to Sowińska-Świerkosz and García (2021) NBS is a contest concept with a broad and blurred framework, but two of the most commonly cited (Bianciardi et al., 2023). The first, developed by International Union for the Conservation of Nature (IUCN), 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"* (p2, Cohen-Shacham et al., 2016). The second developed by the European Commission defined 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 developed by transnational actors claim that NBS will contribute to transformative social change (Woroniecki et al., 2020) by bringing together other 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). A key departure in the NBS definitions is the delivery of co-benefits such as biodiversity enhancement, carbon sequestration, innovation, improved health and well-being, and social cohesion (Collier et al., 2023).

The role of NBS as a vehicle for social change has been challenged by some scholars (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 a lack of definition, blurred and pluralistic framing could lead to unintentional inequitable distribution of NBS benefits Pauleit et al., (2017); Woroniecki et al., 2020; Sowińska-Świerkosz and García, (2021)). Loughran (2020) argues that urban greening has a long history of being perceived as a 'solution' or cultural fix to tackle social crises in cities, but Almassy et al. (2017) posit NBS are unlike forms of existing greenspace because the functioning, governance or management has been changed in some way to advance sustainability. Scholars and policymakers 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)). In an attempt to address some of these debates surrounding the definition of NBS, the EC Horizon 2020 project, NATURVATION, 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).

2.2. Quality of life

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). It is a complex construct influenced by internal psychological and physiological mechanisms that affect how people perceive, but also the relationship with their environment, daily routines and external influences such as education, housing conditions and income that influence a given place or geographical settling (Pacione, 2003; Mensah et al., 2016; Macku and Barvir, 2022).

Despite use of QoL by academic researchers, policymakers and practitioners, there is no single or universally accepted QoL indicator or index, but it can be approximated by constructing an index based on individual measures of contributing elements that relate to QoL's subjective and material factors (Land and Michalos, 2015; Macku and Barvir, 2022). 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 & 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 characteristics of NBS across the landscape and the social determinants of capital accumulation. These determinants are spatially differentiated across Europe leading the European Union (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 achieving economic convergence, the European Union aim to reduce socio-economic inequalities and improve the QoL of its citizens (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 with similar socio-economic characteristics (referred to as the club convergence concept). However, despite convergence among some states, 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 (Davies (2017; Beckfield, 2019; Lammarino et al., 2018).

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 the 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 (Agyeman 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 & 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 characteristics of NBS relates to the uneven geographies of QoL across Europe.

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 used, exploratory data analysis and statistical profiling undertaken.

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 distinct types of NBS, the type of innovation and their respective transferability and novelty was collected using discourse analysis of secondary data sources (such as project reports, web-based sources) (Almassy, 2017). The UNA includes frequency count 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. Based on a review of the literature pertaining to green and blue spaces and their respective typologies, Almassy et al. (2017) categorised each of the NBS into one of eight types of ecological domain (see Table 1) which included NBS implemented in the past (from the early 1990's) as well as a number of planned interventions (Naturvation, 2017). Table 1 summaries the indicators that represent distinctive characteristics of NBS used to explore how the distribution of NBS relates to different social and economic conditions that influence QoL. Some textual commentaries accompany categorical variables to add context or further explanation regarding the variable in question. Fig. 1 shows the cities that were selected by the

NATURVATION for inclusion in the project which formed the sample of cities that were included in the study. Following the approach developed by Almassy et al. (2017), the study used autonomous counting (i.e., frequency counting) and normalisation (see Section 3.3) to profile frequency distribution of the key characteristics of NBS for each city, country and macro region shown in Fig. 1 to help illuminate the distributive features of each of the characteristics of NBS.

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) mortality-related indicators (European Communities, 2004). These indicators play a central role in capturing the everyday realities of poverty and serve to clarify the significance of confronting different social challenges such that intersect with deprivation such as employment prospects (or lack thereof), educational disadvantage, poor health, inadequate housing, and exclusion from the labour market. Based on a review of the literature, only indicators that could be used as proxy variables for QoL indictors were selected for the study. Table 2 lists each of the social and economic indicators published in the Urban Audit that were used in the study.

3.3. Exploratory Analysis & Thematic Mapping

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, exploratory analysis (Ghosh et al., 2018; Rogerson, 2015) of social and economic indicators published in the Urban Audit was completed for each city shown in Fig. 1. The study drew on the Urban Audit as secondary data source because it is one of the few pan-European datasets that are available which permit comparison of different social and economic conditions between cities and different regions of Europe. To begin exploring how the different social and economic conditions in cities relate to the pattern of distribution of NBS, descriptive statistics for each indicator shown in Table 2

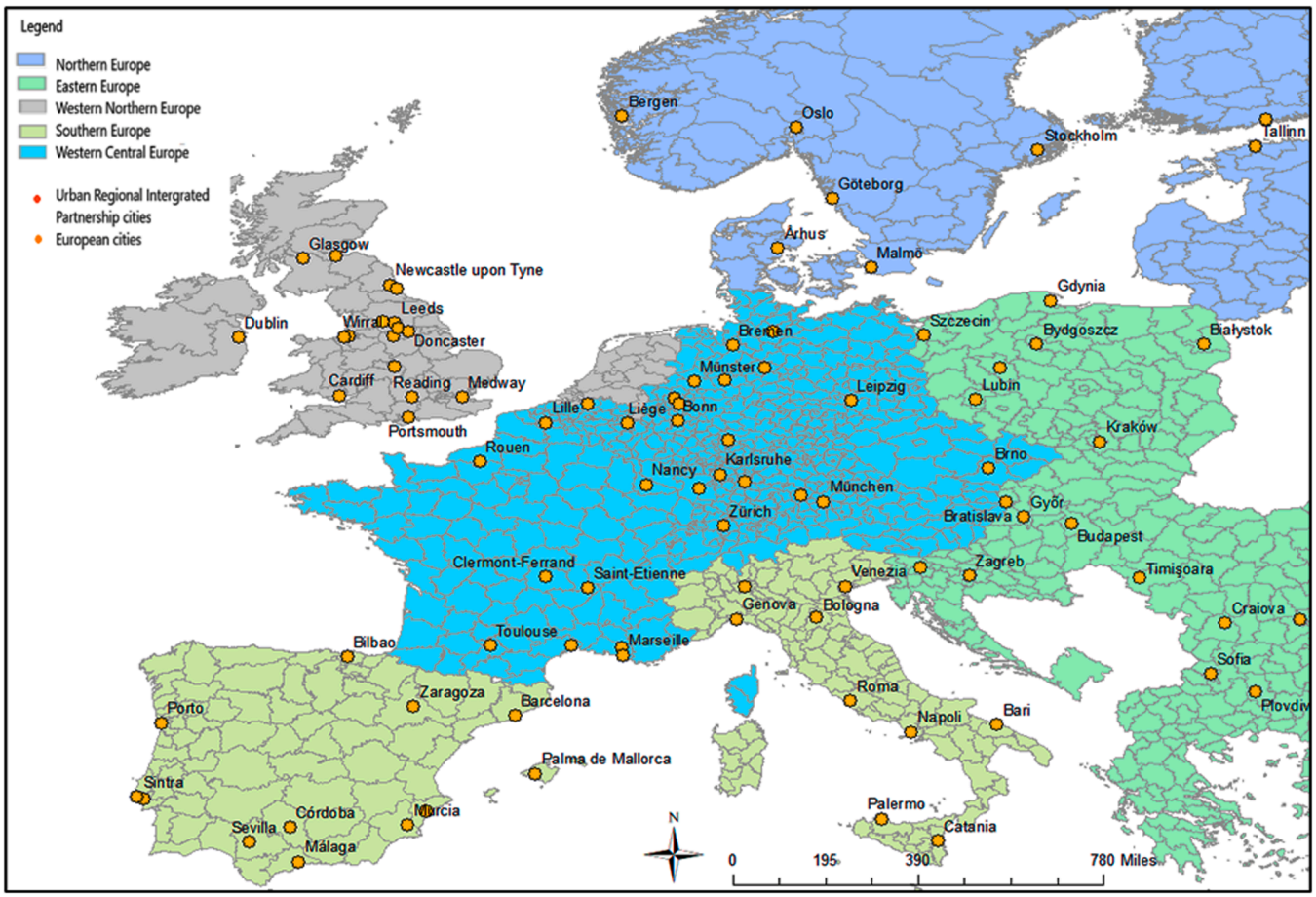


Fig. 1. Map of cities selected for analysis by the NATURVATION programme, including Urban Regional Innovation Partnerships (URIPs) (adapted from Almassy et al. 2017).

Table 2
Quality of life indicators published by the Urban Audit adopted in this study (Eurostat, 2017).

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
Statistics on income and Living Conditions (SILC) Occupation indicators	The average size of living space		

were calculated.

One of the key challenges for analysis was the granularity of available data published by the Urban Audit. Data on each indicator are published for three spatial units: Functional Urban Area (FUA), Greater City and City (Fig. 2). 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 descriptive statistics for each city showed availability of indicators for each unit suggests that they vary in quality and quantity with some missing by reference year and by city. To minimise these effects, the study selected the FUA unit of analysis analyse the pattern of missingness in each dataset (Rubin, 1987).

Following exploratory data analysis, the study used the MICE package (R Core team, 2022) to impute and fill-in missing values using predictive mean matching and the margin plot function. On confirming the pattern of missingness, ten successive iterations were complete for each missing parameter and the distribution of the observed and predicted variables generated by each iteration were compared. The new datasets were converged using the Pool function in MICE after considering the variance across each dataset (Van Buuren, 2018).

Descriptive statistics, cross tabulations and thematic maps were created in ArcGIS to help visualise the spatial distribution of the NBS, social and economic indicators to analyse interrelationships between different variables across and between cities, Member States and European Regions. Each city of the 100 cities shown in Fig. 1 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

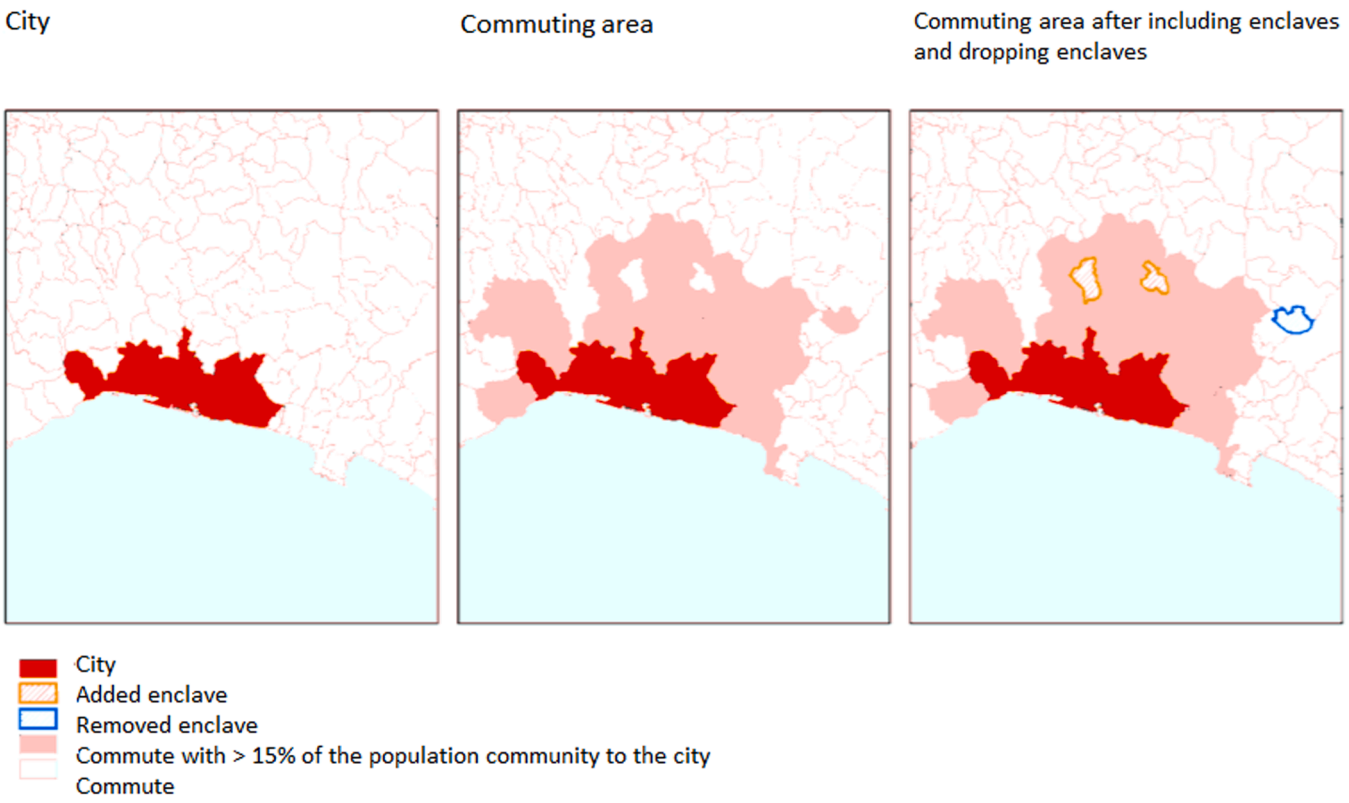


Fig. 2. Definition of a functional urban area (source: European Union, 2017).

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 based on the approach developed by NIST (2017).

4. Results

4.1. Characteristics of Nature-based Solutions

4.1.1. Urban settings of NBS

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. Of these domains, large urban parks formed the greatest proportion of NBS published in the UNA in Western, Northern and Southern Europe although intra-city distribution of these interventions was not homogeneous. An additional 30%, meanwhile, are comprised of various forms of blue space, community gardens or allotments (Fig. 3). The distribution of different types of blue space and blue-green infrastructure was highest in Northern and Western European while allotment and community gardens were more frequently located in Western and Southern European, but like urban parks the distribution is not homogenous across each city. 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, were found in less than 25% of these NBS. The latter is primarily located in Western and Southern European cities but are largely absent from Eastern European cities, characterised by a lower proportion of urban greenspace (Kronenberg et al., 2020) and lower per capita gross domestic product (Fig. 3).

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

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	

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. Fig. 4 shows the distribution of each type of ecosystem service in each region of Europe. Among these, one could find services pertaining to mental and physical health, or recreation, aesthetic appreciation, or services for tourism. Cities such as Utrecht, Barcelona and Leipzig created NBS that provided a higher proportion of services that could provide opportunities for recreation, improve mental or physical health in contrast to post-industrial cities such as Newcastle and Gyor. Conversely, only 30% of the NBS provided provisional ecosystem services (e.g., urban food production or raw materials) while 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.

The present study's findings indicate that multifunctional NBS (Pauliet, 2017; Frantzeskaki, 2019), characterised by the provision of a diversity of ecosystem services were mainly found 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

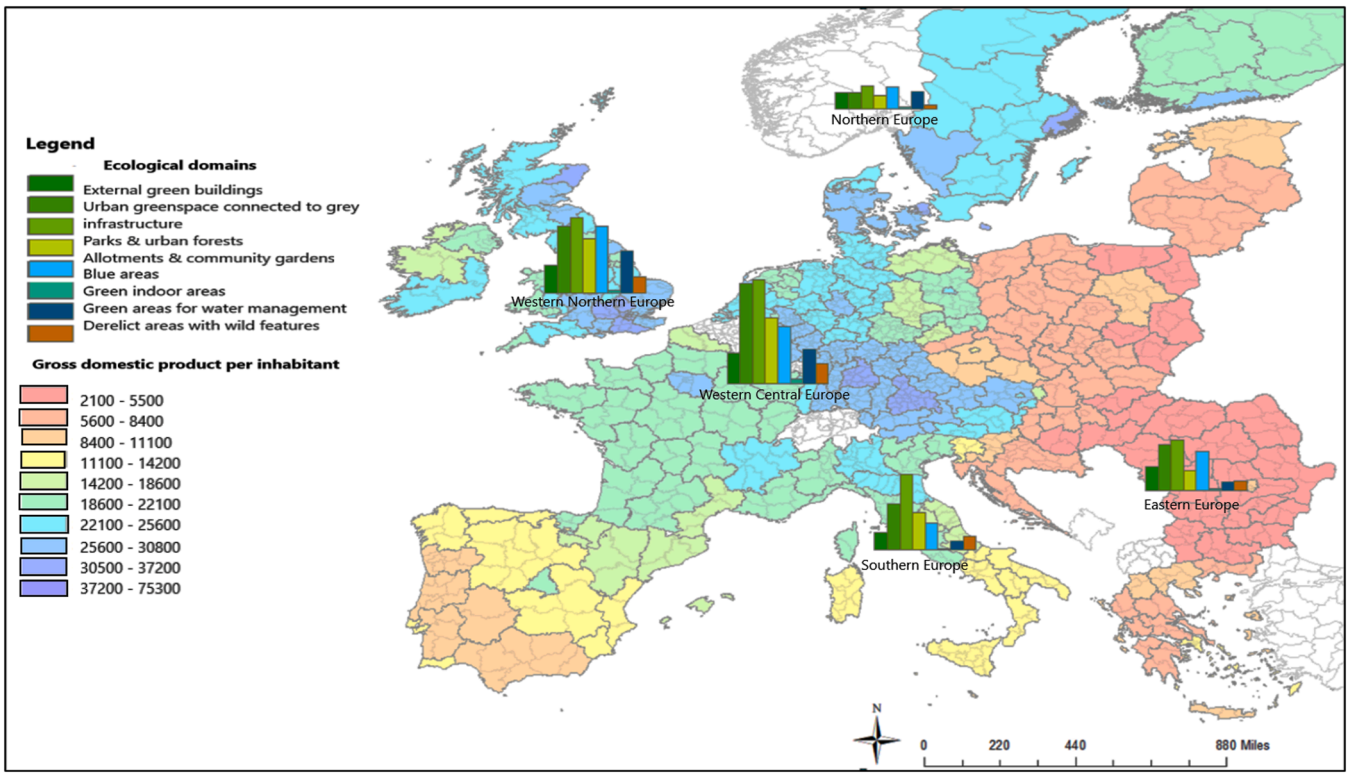


Fig. 3. Distribution of Ecological Domains and Gross Domestic Product across Europe.

study, we define multifunctional NBS as those that have three or more ecosystem services. Fig. 5 shows that Western and Southern Europe have the highest number of multifunctional NBS, as evinced by the distribution of NBS that claim to provide multifunctional ecosystem services. Cross tabulation of 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, 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 was influenced by the number of ecosystem services created by an NBS.

4.1.3. Governance Arrangements and Mode of Participation

The NBS governance process across Southern, Eastern and Western Europe has a hybrid or co-operative setup involving state and non-state actors in management decisions and decision-making processes. Cities in Northern and Southern Europe had the greatest proportion of NBS that were governed using hybrid or collaborative approaches. Hybrid governance accounted for 45% of NBS in the UNA, while the remainder were divided between government-led (28%) and self-governance (26%) (i.e., non-governmental actors play a leading role in the implementation of NBS). Fig. 6 shows the relationship between the type of governance and the method of participatory engagement. The results suggest that co-governance or governance led by non-governmental actors involved a broader range of participatory methods than government led governance. Analysis also suggests that only 12% of these NBS self-reported engaging society with the oversight, management, monitoring, evaluation of NBS, or citizen science (Fig. 6).

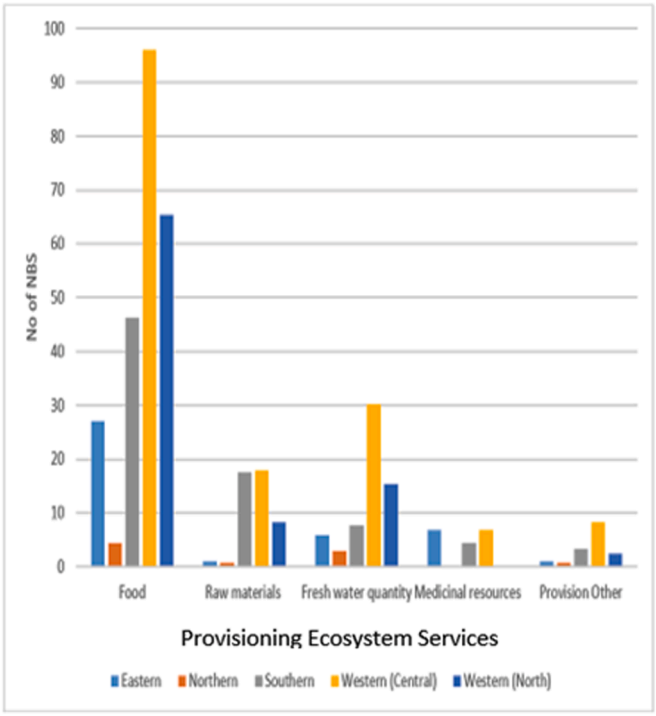
Similarly, NBS, led by state actors or self-governed by private companies, civil society, or research institutions, focus on tokenistic efforts to engage stakeholders such as consultation or information dissemination with only 13% and 10% of projects delegating oversight or monitoring and evaluation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

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

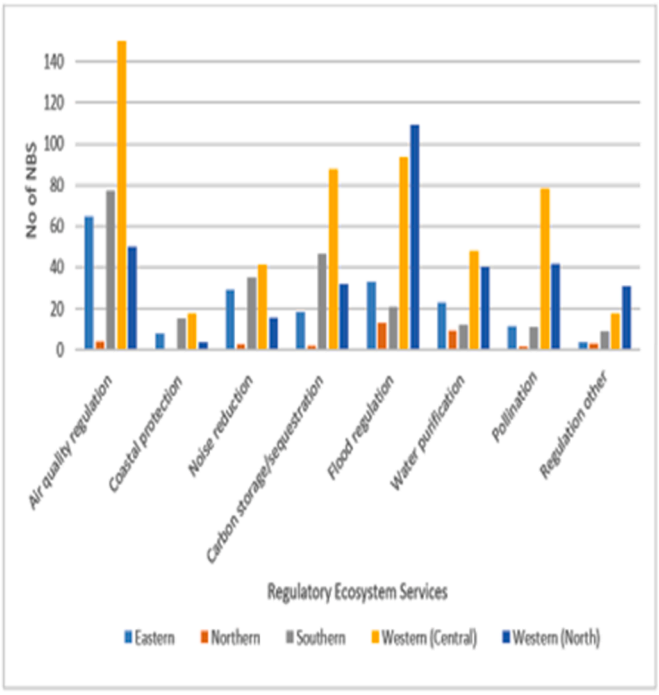
Collecting consistent cost data of the NBS was challenging for Almassy et al. (2017) and resulted in 35% of NBS in the UNA missing this data. Based on available data, 15% of NBS cost less than €100,000, 20% cost €100k – 2 M and 28% cost over €2 M. In over 50% of cases, funding for NBS was sourced from public local authority budgets, while only just over 15% were funded by corporate investment, national or regional budgets, or European funds. Fig. 7 shows the distribution of the number of NBS that fell into each total cost category for each city against the GDP for each inhabitant. While there seems to be no clear trend between GDP and the number of NBS being implemented, some cities with a lower GDP per inhabitant seem to receive a smaller proportion of funding for large scale projects.

4.1.5. Spatial scale of NBS

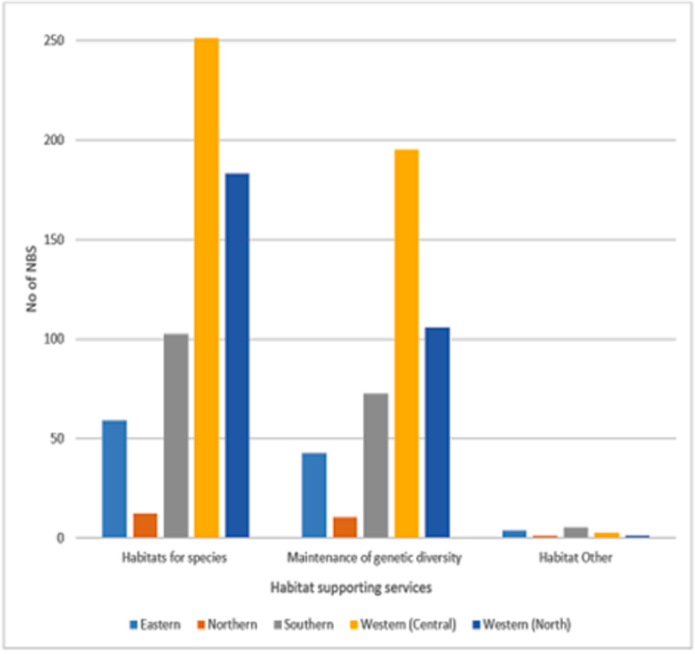
The study also investigated the relationship between governance and the scale of implementation. Four scales were used: macro-scale (global, continental or national), mesoscale (regional, metropolitan and urban level), micro-scale (implemented at district or neighbourhood level) and sub-micro level (street scale). Results demonstrate that 75% of NBS are implemented at a neighbourhood (42%) or street scale (33%), with just 18% implemented at a mesoscale. Our findings also suggest 8% of NBS were 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 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. Fig. 8



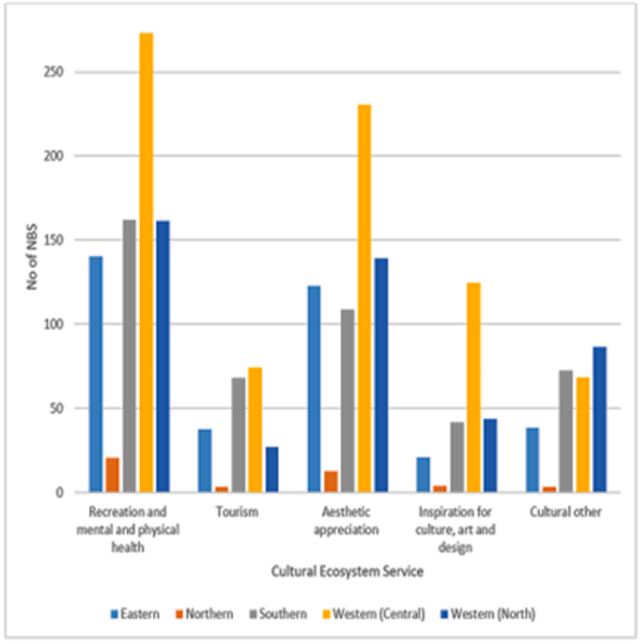
A Provisioning Ecosystem Services



B Regulatory Ecosystem Services



A Habitat Supporting Ecosystem Services



B Cultural Ecosystem Services

Fig. 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).

4.1.6. 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 in particular. More ecosystem services, particularly cultural services, are provided through social governance and cultural innovation NBS (Almassy et al., 2017), 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

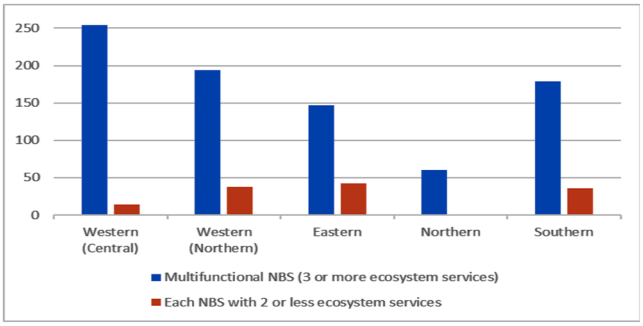


Fig. 5. Distribution of multifunctional NBS across each European Region (based on the sample of NBS published in the UNA).

to systematic changes in socio-ecological-technical systems. Table 4

4.2. *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.

4.2.1. *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 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 (3%) of solutions were located in parts of Western central, Southern or Eastern Europe that experienced record-breaking daily temperatures in 2003 and 2015.

4.2.2. *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 & Cirman, 2012). Such differences make it challenging to compare structural housing indicators reliably. However, despite of the issues reported above 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 follow patterns of distribution in the quality and composition of housing tenure across Europe (Housing Europe, 2021).

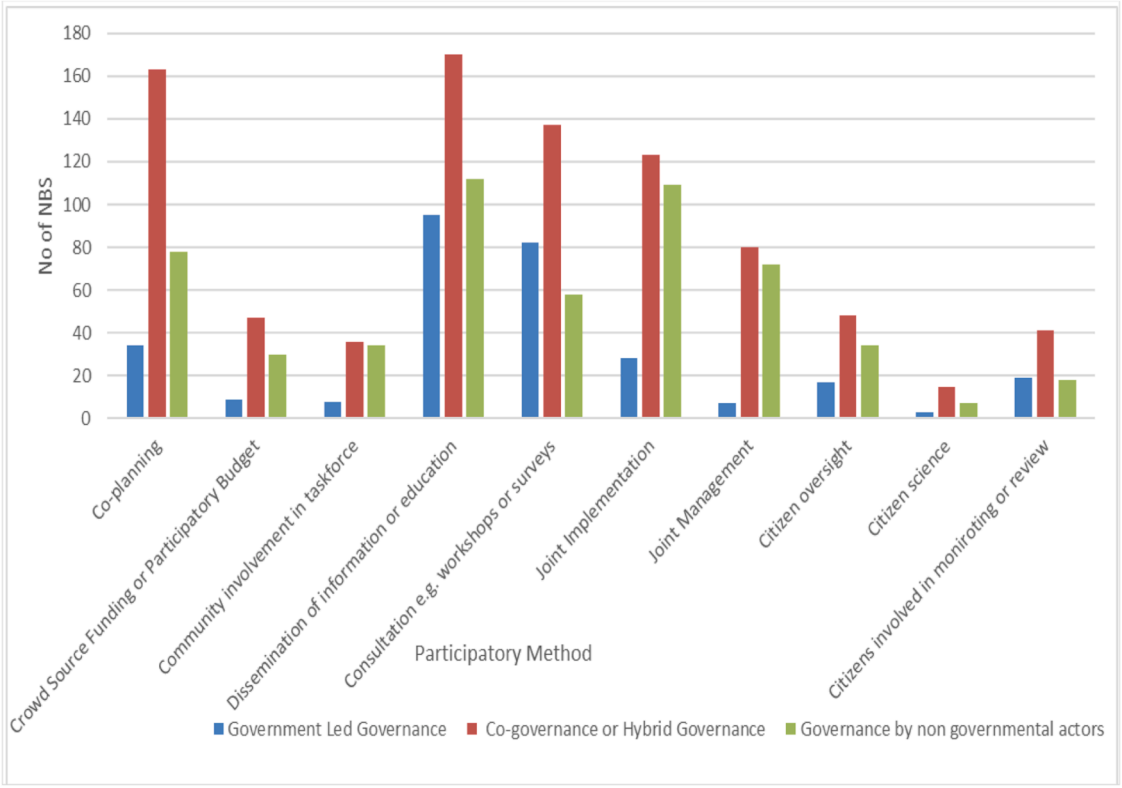


Fig. 6. Relationship between mode of governance and participatory method deployed by NBS.

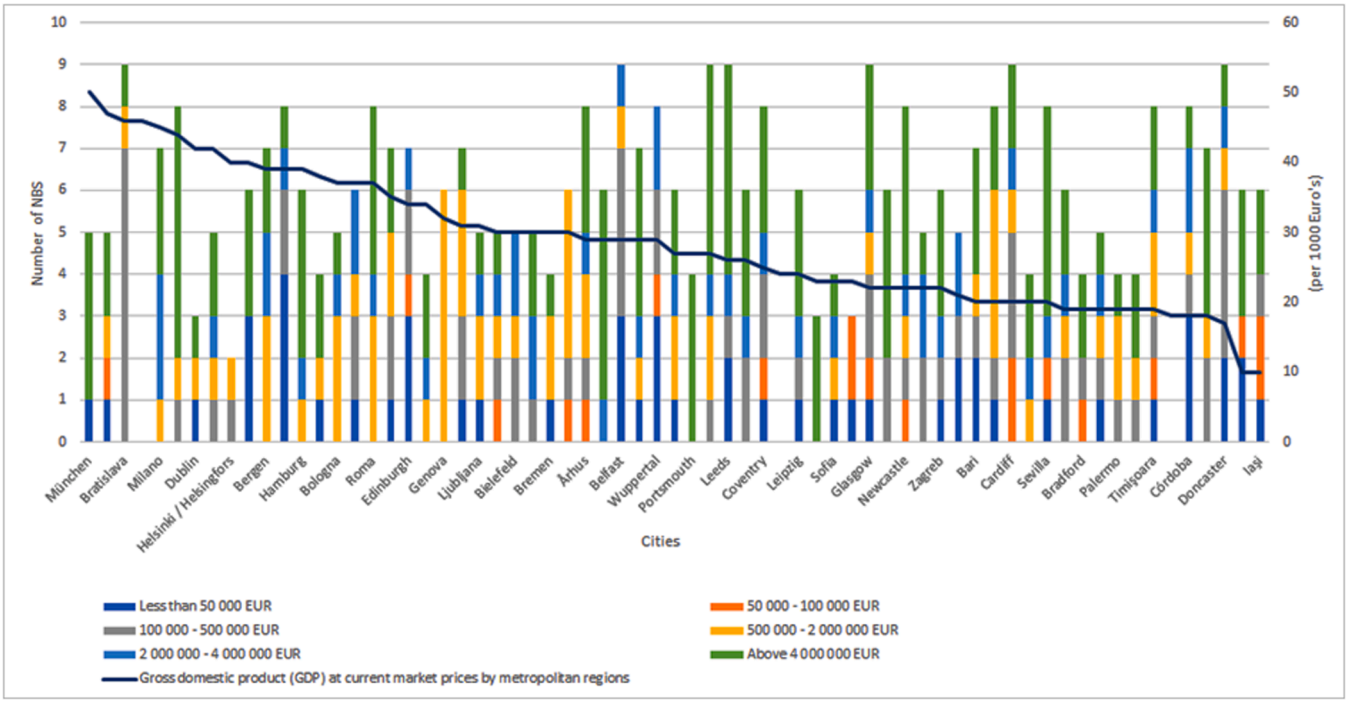


Fig. 7. Comparison of the distribution of the number of NBS, total investment in NBS per city and GDP per inhabitant.

4.2.3. *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 Commission, 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. However, analysis of the description and goals of the NBS in the UNA suggests less than 23 projects (2%), 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 (0.8%) NBS in the UNA aim to create job opportunities or resolve deprivation issues despite an even greater prevalence of social inequality.

4.2.4. *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. This highlights the potential of NBS to help stimulate economic growth and just transitions, especially in parts of Europe where GDP is less than €16,000 (see Fig. 7). 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 shown in Fig. 7.

5. Discussion

5.1. *Distribution of NBS across Europe*

There are significant socio-economic disparities across Europe. Some parts of Europe 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). For example, comparison of median population age suggests it is 1.5 times higher in cites such as Porto and Bilbao than the cities with the lowest median age such as Manchester and Nottingham. These trends are consistent with general trends in an increase in the median population age observed in across Europe (European Commission, 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 & 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). This paper examines the evidence to support these claims by investigating how factors that influence QoL and structural inequality in cities relate to the distribution of the key characteristics of NBS using descriptive analysis and thematic mapping.

Our analysis shows that there is little evidence to suggest that NBS

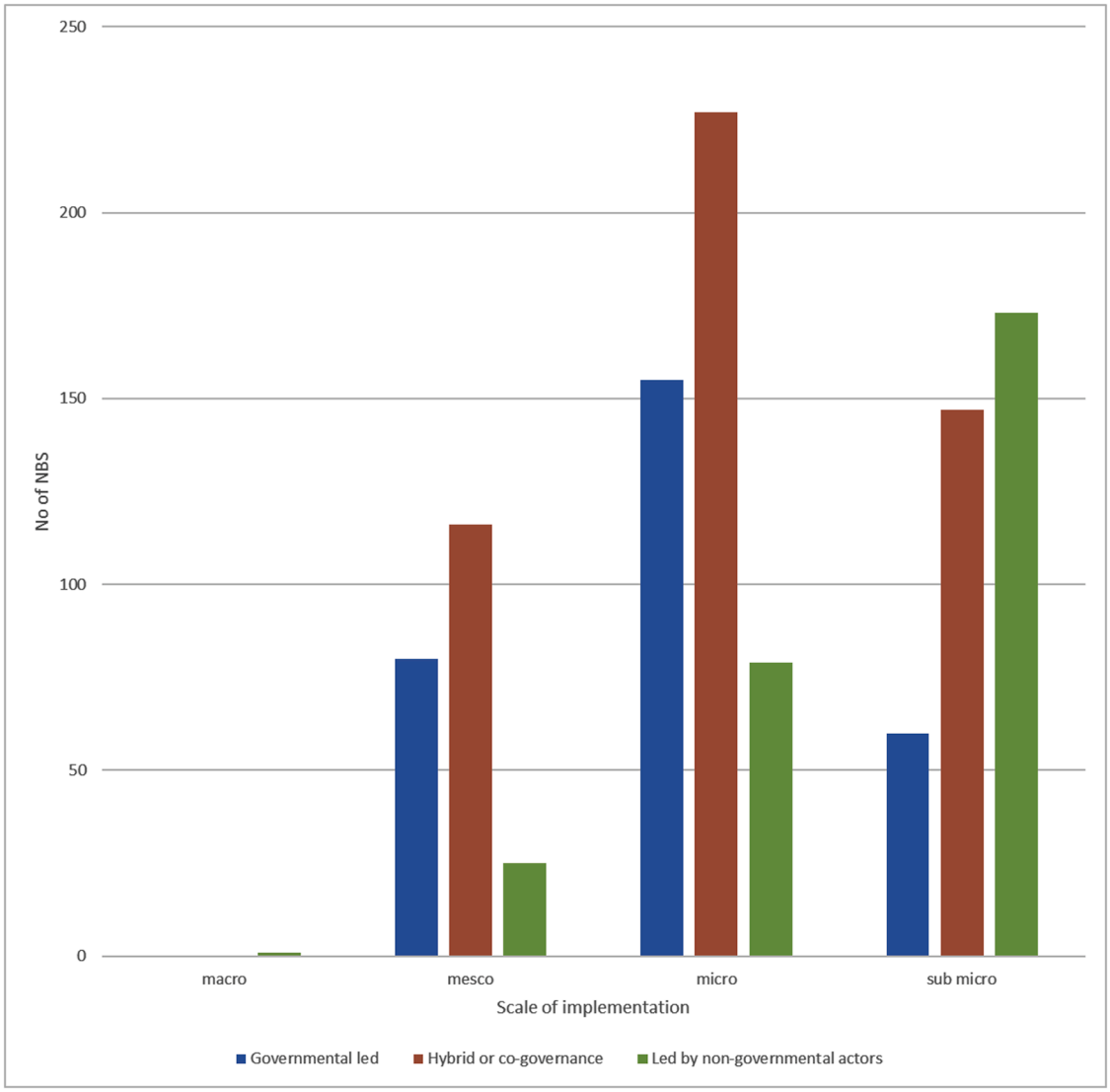


Fig. 8. Scale of implementation of NBS.

have been used to address issues of climate change, biodiversity loss and social inequity concurrently, potentially undermining claims being made by transnational actors such as the World Bank and European Commission that NBS can address multiple challenges at once. Despite the prevalence of poverty, social exclusion and divergence in GDP across the Eurozone, our results suggest that the distribution of NBS follows a social gradient that mirrors the pattern of uneven development across urban Europe. Multifunctional NBS that consist of several different ecological domains and three or more ecosystem services are primarily located in developed economies in Western Europe leading to the unfair distribution of resources that could improve QoL and environmental injustice. Based on these trends, it could be argued that NBS may not be the 'magic elixir for a more just world' (Wang and Lo, 2021 p2), but it is important to highlight that issues of social inequality (such as the prevalence of severe deprivation in cities) may have not been have been a factor influencing the deployment of NBS but may also reflect efforts by these states to protect large areas for biodiversity such as Natura 2000 sites.

While there may be other factors that could explain why the distribution of NBS reflect the distribution of social disparities across the intra-eurozone (Beckfield, 2019), the distribution of financial resources (particularly European investments) also follows a similar trend whereby post-industrial cities (such Manchester, Liverpool and Turin) compete with transition economies to secure investment for urban regeneration in a form of state rescaling (Keating, 2021). Fligstein (2008) argues that developed economies (FTSE, 2018) 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 engage with research structures and cultures more effectively allowing them to leverage finance from the public, private and community spheres through social networks.

These findings highlight the importance of not only considering social justice and equity considerations during the planning and design phase of NBS deployment, but also during the allocation of funding to member states to help enable just transitions in cities by building resilience among vulnerable communities as advocated by the definition of NBS (Cohen-Shacham et al., 2016). In contrast, our results suggest 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) or evidence of a form of enviro-economic privilege among frontier economies driven by what Peck (2019) refers to as 'austerity urbanism'. Peck argues that a shared understanding of the landscape of European Union fiscal policy and the need to demonstrate deregulation and capital efficiency by scaling back the welfare state allows these economies to maintain a competitive edge

Table 4
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.

Frequency of type of ecosystem service	Type of Technical Innovation			Type of Social Innovation				Systems Innovation
	Product	Process	Infrastructure	Policy	Economic	Governance	Cultural	
Provisioning 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

in securing research funding in contrast to emerging or transition economies. Ironically, European policy has led to further economic divergence as marginalised or shrinking cities miss opportunities to secure investment reinforcing patterns of stagnation and uneven development causing issues of distributive injustice, and leading to structural injustice as resources, opportunities for education and skills development are concentrated in more advantaged regions of Europe (Peck, 2019).

The distribution of forms of innovation deployed by NBS also exhibits a similar trend with examples of technical, social governance and cultural innovation most common in Western Europe. This suggests that the region is more advanced in their attempt to transform to sustainability through the deployment of NBS. Critics suggest that such a transformation is more a historical consequence 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 the creation of passive welfare measures and implementation of entrepreneurial strategies 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 be indicative of an idealised or political imagined version of the role that NBS can play in transitioning to a sustainable future among corporate or policy actors.

According to our findings, many NBS appear to foster transformative governance arrangements encouraging a collaborative approach between civil society, and 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 behind their Western European counterparts due to a reliance on European or foreign investments and a lack of skilled labour. These findings suggest that there is much further work to be done to integrate NBS into different policies and thereby help to enable just transition to sustainability, particularly economic convergence policy developed by the European Commission. If left unchecked, there is a risk that financial gains and innovative potential of NBS will continue to be directed at frontier economies hindering just transition in cities and reinforce structural inequalities.

5.2. Relationship between the distribution of NBS and factors that influence quality of life in European cities

Despite the domination of win-win narratives across the NBS discourse our analysis shows that the distribution of NBS across Europe are spatially and socially selective, rarely targeting deprived communities or disadvantaged groups to improve their QoL. This is particularly evident in Eastern Europe, where GDP per inhabitant is significantly lower, and the risk of poverty or social exclusion is higher than in other parts of Europe.

A comparison of the relationship between population growth, age and the distribution of a NBS suggests decline in the age of urban populations in peripheral cities (Lang, 2015) may not have a driver influencing the implementation of NBS. Although divergent trends in demographic change pose significant challenges for cities in delivering 'friendly for all ages' service provision, few cities with stagnant population age structure or a young growing population have begun designing NBS that aim to help the elderly and children cope with climate change-inflicted health issues. For example, a study by Burkart et al. (2016) suggests risk of heat-related all-cause mortality may be reduced by urban green space and close proximity of blue spaces. However, 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) 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 conditions vary considerably across Europe due to differences in ownership, private renting and social housing. Housing deprivation can accumulate due to insufficiencies in primary housing conditions, including inadequate construction, poor amenities and insufficient space (Townsend, 1979; Palvarini and Pavolimi, 2010). Despite being an essential determinant of health, directly affecting it and indirectly influencing the quality of the surrounding area and material living standards (Healy, 2004), less than 25% of cases related to new housing or neighbourhood regeneration and few reflect the gradient of housing inequality or the prevalence of severe deprivation in parts of Europe. Despite the lack of affordable housing and the rise in the number of dwellings with a lack of basic amenities, these findings concur with other studies that suggest investment in NBS has largely driven by place-marketing or greenwashing (Checker et al., 2011; Anguelovski et al., 2021, Schuetze & Chelleri, 2016) or secure foreign investment to rejuvenate shrinking cities following the fall of socialism and deregulation of urban spatial planning (Kronenberg, 2015; Hasse et al., 2019). Furthermore, our found suggests that there are only 23 examples of NBS included in the UNA that are being used as a policy intervention to address place-based inequality distribution in European urban centres. At a macro-scale, this evidence suggests 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 research by Rosol et al. (2017) suggesting 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.

5.3. 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 multiblock 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.

6. 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.

Few cities target deployment and investment in NBS where a lack of essential resources severely impairs resident QoL. We believe this is due to inconsideration of 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.

If left unchallenged this approach could lead to cities reinforcing or even exacerbating inequalities within deprived communities, missed opportunities begin to justly transition to sustainability and potentially trigger 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 social equity considerations may be give more prominence during the design phase of NBS and how these interventions may be mainstreamed to create a broader array of ecological domains and ecosystem services that can simultaneously enable climate change adaption, improve biodiversity and improve the QoL of those that are vulnerable in cities. This work should also investigate the trade-off between the number of services and disservices can impact improvements in biodiversity, climate change adaptation and QoL.

CRediT authorship contribution statement

Niall Cunningham: Writing – review & editing, Supervision. **Louise Bracken:** Writing – review & editing, Writing – original draft, Supervision. **Marcus Collier:** Writing – review & editing. **Clair Louise Cooper:** Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

None

Data Availability

Data will be made available on request.

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