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Re-Thinking People and Nature Interactions in Urban Nature-Based Solutions

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Abstract: People-environment interactions within nature-based solutions (NBS) are not always understood. This has implications for communicating the benefits of NBS and for how we plan cities. We present a framework that highlights a duality in NBS. The NBS as an asset includes both natural capital and human-centred capital, including organisational structures. NBS also exist as a system within which people are able to interact. Temporal and spatial scales moderate the benefits that NBS provide, which in turn are dependent on the scale at which social processes operate. Co-production and equity are central to the interactions among people and institutions in the design, use and management of NBS, and this requires clear communication. Drawing on ideas from culture-based development (CBD), we suggest an approach to communicate the benefits of NBS in a neutral but effective way. We propose guidelines for planning NBS that allow the optimisation of NBS locations and designs for particular outcomes.

Academic Editor: Maria Rosa Trovato

Received: 14 February 2025
Revised: 25 March 2025
Accepted: 26 March 2025
Published: 29 March 2025

Citation: Jones, L.; Anderson, S.; Læssøe, J.; Banzhaf, E.; Jensen, A.; Tubadji, A.; Hutchins, M.; Yang, J.; Taylor, T.; Wheeler, B.W.; et al. Re-Thinking People and Nature Interactions in Urban Nature-Based Solutions. *Sustainability* **2025**, *17*, 3043. https://doi.org/10.3390/su17073043

Keywords: cities; green space; green infrastructure (GI); co-production; ecosystem services; framework

1. Introduction

In a rapidly changing world, our cities face numerous pressures that adversely affect the quality of life for urban citizens. These include thermal stress, poor air quality, risk of flooding and excess noise, all of which can have direct and indirect impacts on human health and mortality [1–5]. There are technical solutions to many of these challenges, but technical solutions are often single-focus, expensive and may have unintended consequences. A more sustainable approach to reducing such urban challenges is to make increased use of nature-based solutions in cities, since these are multi-functional and offer a wide array of co-benefits [6,7]. They are also usually cheaper to implement than technical solutions [8].

Nature-based solutions (NBS) have a clear definition: "Nature-based solutions are actions to protect, sustainably manage and restore natural and modified ecosystems in ways that address societal challenges effectively and adaptively, to provide both human well-being and biodiversity benefits" [9]. However, there are still limitations to what people understand an NBS to be, and in the way NBS activities are implemented. In particular, there is frequent misunderstanding of the role of people in NBS, and a lack of understanding of how the spatial interdependencies of NBS and their surroundings help shape the functions and benefits they provide.

The role of people in environmental systems is traditionally seen as linear/cyclic, either as recipients of benefits from the environment at the end of a suite of processes, and/or as managers of the environment [10]. The strongly linear interpretation of a sequence of environmental components and processes leading to human benefits is in part a result of early conceptualisations such as the Cascade model [11], which was initially developed as a framework to help make sense of the role of biodiversity within the concepts underpinning ecosystem services. This linearity is reinforced by many economic approaches to quantifying ecosystem services, such as the Final Ecosystem Goods and Services model of Nahlik et al. [12], which identifies a point of hand-over of the ecological production function to the economic production function, allowing the attribution of economic value to environmental components. Later, more holistic frameworks have sought to describe these roles within a social-ecological system bounding box [13,14], although this is often rather imprecisely articulated. In such frameworks, the interactions of humans within the system tend to be restricted to feedback loops rather than recognition that humans are an integral part of the whole [15]. However, there is increasing impetus to specify multiple roles of people, where they are integrated within the system and necessary to create the ecosystem services that lead to societal benefits, as well as being governors/managers of the system, and lastly to specify the role of humans as users/receivers of benefits provided by the system [16,17]. A recognition that people are an integral part of natural systems is particularly important in cities where >50% of the population live globally, rising to a more than 90% urbanised population in some countries (e.g., Belgium, The Netherlands, Argentina, Japan) [18]. It is also important to recognise that within cities, natural spaces are almost always modified, managed or even fully created by humans. While the conceptualisation of people and nature in cities is constantly evolving [19], recognising the central role of people as part of the system is an important step towards changing the perspective on how to manage NBS.

Somewhat surprisingly, the role and definition of natural elements in cities also contains gaps. The first commonly used term, Green Infrastructure (GI), is defined as the "interconnected network of natural and semi-natural areas, features and green spaces

that support native species, maintain natural ecological processes in rural and urban areas, and contribute to the health and quality of life for human beings" [20]. This definition specifically includes ideas of connectivity and position within a landscape setting. The concept of GI has further been expanded to include green and blue infrastructure, with recognition that blue features are under-studied in this context [21]. More recently, the concept of GI has been somewhat enveloped by nature-based solutions (NBS), defined above, where the definition moves beyond that of GI with the distinction that NBS are created or managed for a purpose, which explicitly incorporates biodiversity and benefits for people. In all of these conceptual definitions, a gap emerges—it is hard to find a widely accepted generic term for the basic units of green and blue semi-natural spaces in cities. Some authors use the terms green space or blue space, particularly in the health literature [22,23], but perhaps at their core these spaces can be considered elements of natural capital (or hybrid capital if we think of constructed features combining grey, green and blue elements). The idea of different forms of natural and human capitals can help better understand and attribute the role of people in the highly complex inter-connected social-ecological system that constitutes a city [16,17].

The public perception of NBS also has a bearing on how the benefits of NBS are communicated, both to policy-makers and the public. The rationale for creating new NBS or changing current city layouts or functions can be highly contentious [24], because people are resistant to change. The public debates around new greenspace or changing infrastructure or transport systems are often highly polarised between those seeking an environmental or social benefit (for the greater good), and those who see a restriction to individual freedoms, particularly their own [25]. Here, new theories in economics, such as culture-based development (CBD) [26,27], can perhaps help with the framing of benefits in a more neutral way.

There is therefore a need for a clearer understanding of how the human elements (built structures, people) and the natural elements (soil, water, plants, insects, animals, the processes that interlink them) within cities all interact to provide the functions for which we manage NBS. This is critical to designing more liveable cities for the future. It requires a different way of thinking about what constitutes NBS, and how best to design them or plan their locations to deliver benefit, which in turn can improve the sustainability of our cities using NBS to address multiple societal needs.

The objective of this paper is therefore to introduce and develop a conceptualisation of NBS, which at its core represents those complex interactions between natural components and people, which are essential to providing ecosystem services. We present a framework that describes NBS in an urban context, acknowledging the contribution of natural capital and other forms of capital to NBS, and the people-environment interactions that deliver the ecosystem services, resulting in wellbeing benefits in cities. The framework allows us to better plan and manage more sustainable cities for the future, taking account of spatial context. The paper is structured as follows. Section 2 describes the scoping of the framework. Section 3 describes the development of the conceptual framework and its application in an urban setting. Section 4 builds on these ideas to discuss the implications of how applying the framework might change the way we plan and design NBS in cities in the future. Section 5 concludes the article.

2. Conceptualisation of the Framework

The conceptual framework was developed through a series of discussions among a multi-disciplinary team of researchers from natural science, humanities and social science, NGOs, city and municipality officials and NBS practitioners from Europe and China. The framework was designed firstly to represent the following elements, which were

identified as important in complex urban systems, and secondly to be a tool that enables transformative thinking:

- Integration of people and nature;
- Multi-functionality of NBS;
- Scale (spatial and temporal aspects);
- Quality of NBS;
- Co-production;
- Incorporating pressures and drivers;
- Governance and urban policy making;
- Education and learning;
- The role of public and private interventions to create, manage or improve NBS.

A number of system frameworks were considered to guide this process. These included named frameworks such as eDPSEEA, DPSIR/ES, MAES, EKLIPSE and the human ecosystem framework [13,14,28–30]. While the aim was to build on these as much as possible, they typically lack emphasis on some aspects that are particularly important in an urban context. Key limitations include the linear/circular nature of the vast majority of existing frameworks, which show people as end users or receivers of a linear (or circular) sequence of processes, rather than as active participants in shaping and forming the service and benefit. It should be noted that Pickett [29] is an exception here. In other words, co-production, and the dynamic nature of benefit, are inadequately addressed in most existing frameworks. A second aspect, which is particularly relevant to urban settings, is that most NBS in cities are actually a complex mix of built infrastructure and natural components. For example, a green wall contains plants that are housed within a sophisticated built infrastructure, which comprises artificial cells containing soil for rooting, a physical framework to support the plants while they spread and an irrigation system to provide water and nutrients. The natural capital here is almost entirely dependent on the built infrastructure for its survival. Towards the other end of the spectrum for urban NBS, a large wooded park appears more natural but still has human input in the form of planting and maintenance of trees and lawns, and built infrastructure (such as surfaced paths, benches, cafes and toilet facilities), which inherently contribute to the potential of the park to provide multiple benefits, including social interaction and recreation [31–33]. Therefore, any framework needs to adequately recognise this combination of natural features and human elements.

3. Description of the Framework

The framework (Figure 1) builds on insights from a number of studies. Its core elements are based on an existing framework that strongly emphasises co-production, and that explicitly recognises combinations of natural and human-centred capital [16,30]. These forms of capital should not be interpreted in an economic context, i.e., where an economic value must be attached, but rather as the core building blocks that make up social-ecological systems. Natural capital includes components linked to geology, soils (pedology), water, biodiversity and the atmosphere. Human-centred capital encompasses (i) built capital (also sometimes called produced capital), like buildings or drainage infrastructure, (ii) human capital, which is the embodied capital in people as well as the knowledge and skills they hold, (iii) social capital such as social networks, connections and mutually recognised practices, and forms of governance, (iv) cultural capital, which covers peoples' value systems, perceptions, norms, identity, world views and beliefs and (v) financial capital. More extensive definitions and examples of these forms of capital can be found in Jones et al. [30].

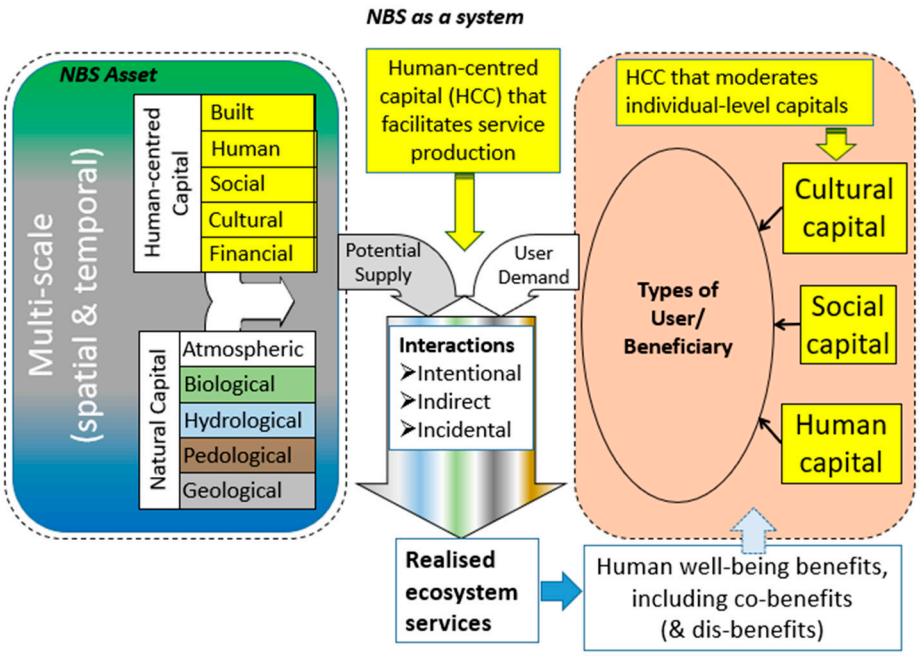

Figure 1. Conceptual framework for delivery of benefits by NBS in urban settings, adapted from Jones et al. [30].

The framework has been broadened to place the mechanisms by which ecosystem services and benefits are generated (Figure 1) into the wider context of urban settings (Figure 2). These include some of the pressures faced in urban areas, together with an understanding of where the use of NBS allows a more sustainable approach to improving the liveability of cities. These actions or interventions range from ones that are more nature-focused to ones that are more people-focused. We discuss below how the key components are represented in this framework. The framework separates NBS as an asset (or entity) from NBS as a system. The NBS asset comprises the bio-physical and social structures that make up an NBS, and it has the potential to provide ecosystem services to people. The NBS system comprises the myriad daily interactions of people with the asset, which result in benefits to society, as well as the higher-level governance structures that manage it.

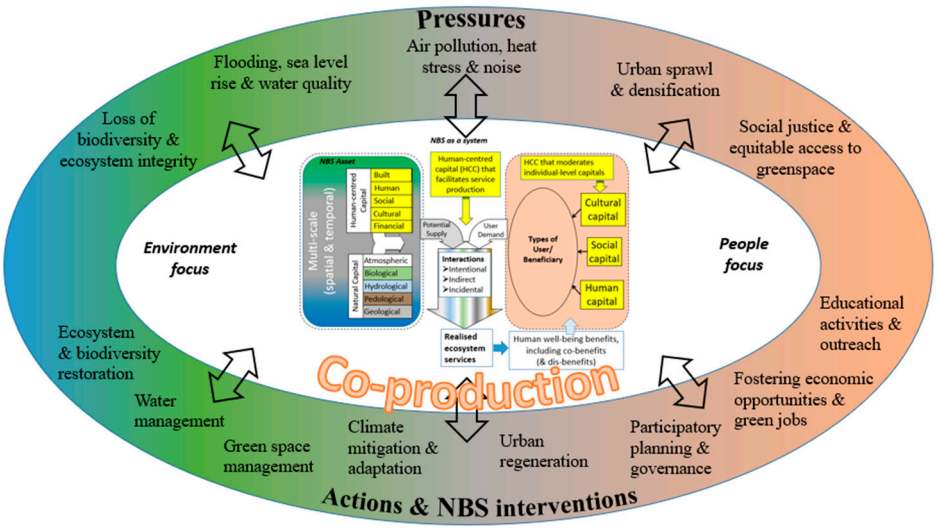

Figure 2. Conceptual framework showing how NBS actions can deliver solutions in response to pressures.

3.1. NBS as an Asset

Cities are a complex mix of built and natural capital. NBS in cities will all contain both natural and human capital in varying amounts. The left-hand side of the diagram in Figure 1 therefore represents the NBS asset, with its mix of combined natural and human-centred capital, which together determine its potential for use and interaction. Taking an urban park as an example, the natural capital elements within the park include the geology and topography (geological), the soil (pedological), biodiversity (flowers, trees, insect and animal species) (biological), water features (and their water quality) (hydrological) as well as the weather (atmospheric) and their interactions [34–36]. All of these make up the natural capital features of the space. These are complemented by the human-centred forms of capital, also embedded within the park, and are extremely important in defining how much service that park can provide to users [32]. This includes built capital elements, such as buildings, benches, trash bins and sealed paths which increase the user experience and accessibility and, if positive, lead to greater public use [37,38]. It also includes other forms of human-centred capital, which help maintain or govern the park: financial capital which pays for maintenance of the park, human capital in the form of the gardeners who do that maintenance, social capital in the form of the capacity of institutions and governance mechanisms for the park, and cultural capital, which includes the public perceptions or image associated with the park. This combination of natural and human-centred capital defines the potential of the park to provide a range of benefits to society. This can also be seen as a precondition or 'what is there' from the outset.

3.2. Types of Users/Beneficiaries

The box on the right side of Figure 1 represents beneficiaries. These encompass all the people who may use the NBS, for whatever purpose, recognising that they will have different needs or patterns of use of the NBS. Here we define different 'types' of beneficiaries as a way of recognising that different users will have a range of requirements, which can guide decision making on how a particular NBS should be designed or managed. For example, are they socio-economically deprived, vulnerable (which may include children, elderly, disabled people, or other marginalised members of society), or do they live in particular areas of the city which increase their exposure to pressures such as noise or air pollution [39]. Visitors to parks tend to use them in different ways, and for different visit durations depending on whether they are local or have come from further away [40]. Motivations may also differ according to the type of beneficiary, for example Home et al. [41] found that younger residents visiting NBS wanted to escape and reflect, while older residents were seeking social contact. The social ties, place attachment, and civic participation of NBS users also determine how they interact with that space, and consequently the benefits they receive [42]. All these different dimensions of beneficiaries' needs and desires will influence how NBS interventions can be designed, implemented and managed to improve access to benefits and well-being, and to minimise negative impacts.

3.3. NBS as a System—Interaction Between People and Nature

The framework recognises that the benefit only happens from the combination of potential for an ecosystem service to occur and the activated demand for it among users (when the two arrows meet in the middle). The 'realised' ecosystem service and the benefits are defined solely through the interaction of people with the NBS asset.

The nature of the interaction between people and the environment in this context can take different forms: Intentional, indirect and incidental. These definitions expand on those in Keniger et al. [43]. Intentional use might involve going to a park to relax after work, walking your dog in the park, or meeting family and friends there. Examples of

indirect use include trees in the park removing CO_2 from the atmosphere, reducing the risk of flooding, or reducing the air pollution concentrations that you experience, and so the park contributes indirectly to your health and wellbeing. Another example of indirect use would be seeing a park through a window or viewing images of a park online. Incidental use might occur where you travel past the park on your normal route to work and this exposure to greenspace contributes to your wellbeing. The framework also recognises that interactions of people with the NBS are likely to result in multiple benefits or co-benefits, and potentially also some disbenefits such as exposure to biting insects [44].

3.4. Drivers/Pressures, Actions and Interventions

Drivers and pressures influence the combined NBS social-ecological system, and for convenience we refer to them collectively as pressures. The pressures listed in Figure 2 are not exhaustive but cover some of the main challenges that affect quality of life for city-dwellers and situations where there is scope for NBS to provide part of a more sustainable solution. They include increased population growth leading to growth and change in the city extent, form and density as well as increased demand for ecosystem services [45]. They also include pressures linked to air, water and the climate, as well as social factors such as increases in social inequity, and the breakdown and loss of cohesion of urban neighbourhoods, health and wellbeing [46]. The loss of biodiversity is framed as a pressure here, in the same context as poor air or water quality or an increased risk from flooding, but these could alternatively be seen as an impact of the pressures and therefore as an emergent property of impacts on the city system.

The actions and interventions are human management responses and levers to create a positive change in the system. Specifically, they are interventions that have a bearing on the use of NBS as a more sustainable part of the solution, in place of purely technical solutions, which tend not to be multi-functional. Our novel framework shows that there are three different leverage points on the system: interventions can focus on (i) the biophysical components of the NBS (creating species-rich grassland on road verges, planting trees near a school for educational purposes), (ii) the built capital components of the NBS (toilets in a park, a cycle path along a canal, managing public space next to the sea [47]) and (iii) the perceptions that beneficiaries have of the park or of the governance of the system to increase the use or desirability of an NBS in the mind of beneficiaries. The framework makes clear that both pressures and actions can operate on any part of the system. In reality, although pressures tend to operate at the city scale, there are often hot-spots where particular pressures are greatest [48]. Meanwhile, interventions tend to be undertaken at the neighbourhood scale, for a host of reasons including cost, the availability of suitable locations and the tractability of implementing solutions.

3.5. Wider Social and Economic Components—Governance, Business and Education

At a level above the day-to-day interactions that deliver benefit are the higher-level governance and administrative systems that influence the NBS. These social and institutional structures, conceptual systems, information flows and interactions are also specific forms of human-centred capital. Thus, governance is incorporated within policy institutions central to the decisions on and management and design of NBS [49] and is considered a component of social capital. Meanwhile, business can provide financial capital but can also innovate and provide input to the design, management and creation of new NBS by bringing together human capital in the form of knowledge as well as social capital through institutions or networks set up to create or manage novel NBS [50].

Education can feature in many ways. Teaching is a form of interaction itself designed to transfer human capital in the form of knowledge but can also make intentional, indirect

and incidental use of the awareness and educational benefits provided by NBS as part of the teaching process [51].

These elements in the framework operate across multiple scales and are relevant to the management of an individual NBS asset such as an urban river, a street tree or a roadside verge, as well as the larger urban system.

3.6. Co-Production

In our framework, co-production is central to the interactions among people and institutions that take place around the design and management of NBS. Co-production is a participatory policy-making and/or planning process in which people, as citizens, communities and/or users, not only are consulted but are offered a role as genuine participants in the whole process, from exploratory reflections, the conception of the issue, decision making, the design of potential solutions, implementation and evaluation [52]. This may be driven and motivated by people's place attachment and cultural identity [53], linking citizens to the local cultural context where NBS are developed. Thus, in the diagram, co-production encompasses those interactions among people, governance institutions, financing agencies and those who are end users in order to address these urban challenges. Ultimately, this should result in better quality NBS that meet the ongoing needs of urban dwellers and biodiversity and that provide a more sustainable approach to reducing the adverse impact of urban challenges than technical solutions alone [54].

3.7. Quality

The quality of the NBS encapsulates this complete package of natural and human elements, and how well it provides a suite of benefits. "Quality" is a complex issue, and the attributes that determine quality may be different for each type of ecosystem service that is provided, or for different types of NBS users. For example, woodland that provides the greatest noise mitigation will have closely planted trunks that will need to be greater than a minimum width [55], but this may not support the highest biodiversity or the best opportunity for recreation or education. Better quality should be understood as the best-fitting NBS for a range of requirements, encompassing wider societal and environmental needs as well as local ones.

3.8. Spatial Considerations in NBS Planning

The above conceptual approach illustrates high-level principles that can help design and manage NBS better. There are also more practical considerations that recognise the complex human–nature interactions that make up the NBS system and can help lead to understanding of the spatial requirements around the scale, location and domains of influence.

Scale is relevant for a number of reasons. In some cases, there are effectively threshold effects where an NBS can only deliver a service when it is above a certain size (noise mitigation by woodland typically requires a tree belt thicker than 10 m [1,55]), or where the level of service provided scales with the area—the larger the woodland, the greater the amount of air pollution it can remove [56] or the amount of carbon it can store. For other ecosystem services, such as providing opportunities for recreation or supporting wellbeing, scale may be important but not as critical. As long as the accessible greenspace is of a certain size (the WHO recommendation is 1 hectare [57]), the additional benefits for recreation or wellbeing may depend as much on the quality and attributes of the green space [34] as how large it is.

Building on the ideas of both scale and location, the spatial domain of influence is important in multiple dimensions. These can be summarised as "sheds", drawing on the ideas of watersheds [58,59]. Environmental pressures have their own spatial domain,

ranging from global or hemispheric for some air pollution components to highly localised for some sources of noise pollution. NBS also have a zone of influence unique to each ecosystem service they provide. For example, they reduce flood risk or improve water quality to certain distances downstream. In addition to their air shed, watershed and biodiversity shed, each NBS has a people shed, which defines the spatial area over which people have an interaction with that space (whether intentional, indirect or incidental, according to our framework). The characteristics of the beneficiaries within that people shed and the type of interactions they have with the NBS is incredibly important to designing a multi-functional space [6]. For example, if the majority of the population within the people shed of a planned new NBS are elderly, then the design of that space might give a higher priority to infrastructure such as wide flat paths, toilet facilities and benches rather than children's play equipment. The type of likely users of the NBS may also have a bearing on how the more natural areas are planned and designed.

3.9. Holistic Framing

Overall, the framework allows a more flexible and less constrained understanding of what constitutes NBS. Previous definitions have taken a very biophysical definition (what it is) or functional definition (what it does) of an NBS [60]. Here, we define the NBS system to incorporate not only its full physical structure (including built capital) but also the human interactions, public perceptions and governance structures that enable it. In this way, a functioning NBS, which truly provides benefits, means not only that the bio-physical structures are in place but also that people are able to interact with or use it. Underpinning the framework is a recognition of the complexity of scaling effects. The temporal and spatial scales can moderate or influence the benefits that NBS provide, and those benefits may be dependent on the scale at which different ecological and social processes operate [61].

3.10. Understanding NBS Within an Economic Theory Perspective

The combination of natural and human-centred capital is termed in economics as the endogeneity of the ecological public good [62]. We highlight here through the NBS framework that this endogenous interaction is what generates and ultimately defines the final potential of the public good (e.g., a park, a roadside verge, a cemetery) to provide a range of benefits to society.

Taking a step back, the inherent tensions in some of the public's reaction to greening initiatives in cities can be explained through economic theory. Public goods are seen as difficult to manage as they are shared in ownership that exists on the aggregate level in society. A problem with welfare policy and its corresponding maintenance of public goods is the philosophical stand that the policy-maker and politician know the best way to manage public goods, which can be seen as paternalistic, and which can limit individual freedoms (even if it is for the greater good). Contrasting with this is the libertarian idea that everyone should be free to desire and obtain according to one's desires, as long as no harm is conveyed to others by doing so [63].

A key point here is how one defines harm. Where harm is defined in a cultural context, there is scope for different definitions of harm. Specifically, people who are supporters of the green idea will define harm as something bad to the environment. Yet, for individuals who deny the existence of global warming, etc., the limitation of their freedoms for the use of the public good based on global warming concerns will be considered harm to their freedom. Thus, any definition of harm from one perspective may be seen as paternalistic by those with different views.

We suggest that a value-free analysis of values, as suggested by culture-based development (CBD) [26], is a possible solution in principle to this "culture-defined" harm. CBD

suggests that instead of asking if a factor is good or bad from a particular perspective, harm can be centred around a definition that is "nature-based". For instance, one may ask if a policy action will increase or decrease a certain outcome. Thus, instead of culturally labelling a policy intervention as good or bad, a value-free objective assessment can establish whether an intervention will increase or will decrease the positive spillovers in the system. Objective information can empower people to overcome their own ideological constraints and may decrease the polarisation in perspectives [64].

The CBD paradigm focuses on culture as a source of bias in individual and group decision making. Essentially, CBD states that due to their possessing different cultural capital, people as individuals, or as managers and policy-makers, are always making human culturally biased decisions. The cultural rationale of people differs systematically according to their cultural capital, which not only underpins their identity and the structure of the system they operate in but also defines the costs and benefits from the socio-economic systems that they will value and that will be socially facilitated to access. CBD calls this the cultural endogeneity of the economic system.

In our NBS framework, Figure 1 shows that all the human elements (in yellow) relate directly via cultural capital or indirectly through other forms of human capital to determine the values and behaviour of both the beneficiaries and managers of the resource [65,66]. Thus, the cultural capital of those designing and implementing an NBS has the clear potential to influence how it is designed and ultimately can lead to a very different set of intentional, direct and indirect interactions emerging. This might drastically limit the benefits for some sectors of society.

4. How We Manage Cities, Now and in the Future

4.1. Current Implementation of NBS

We detail four case studies from towns and cities of different sizes to explore how greening schemes are typically implemented in different countries, as a prelude to discussing how our framework might influence planning and design of NBS in the future. These case studies were selected for two reasons: the authors of this study are involved with, or work closely with, the city authorities and so have insights that cannot be obtained simply by searching the published or grey literature; The case studies also give perspectives across cities of different sizes, climates and cultural contexts.

4.1.1. Case Study 1—Rhyl, UK

Rhyl is a small coastal town in Wales, population 27,000, with some pockets of severe deprivation and a level of tree-cover well below the Welsh average. The local authority (Denbighshire County Council) has instigated a programme of tree planting and wildflower meadow creation in the town. The net zero and more ecologically positive 2030 goals include increasing the tree canopy cover and species richness of council-owned and/or -managed land, whilst also creating improved spaces for the community and wellbeing. Potential locations for the planting schemes were identified based on a combination of available suitable land (existing parks with sparse tree cover, and roadside grass-verges) and areas with relatively low tree cover in residential areas. The locations were selected primarily by visual assessment on GIS or town plans, rather than a formal structured assessment of the maximum potential benefit. Some locations are in relatively wealthy neighbourhoods while others are in less affluent areas. Consultation with residents occurs before each location is improved and includes information provided by letters to residents nearby and information online. The community, including local schools, is encouraged to get involved with the tree planting and further volunteer and educational opportunities are planned at these sites after each scheme has been completed to enhance engagement.

4.1.2. Case Study 2—Aarhus, Denmark

Aarhus is the second largest city in Denmark, with a population of 291,000. The city of Aarhus has adopted a policy on "Nature and Green Surroundings In Aarhus (A GREENER AARHUS)", which addresses how to maintain and improve Aarhus as a good quality city for everyone that is able to cope with future high rainfall intensity events and that offers sufficient space for people and nature, while aiming for CO_2 neutrality by 2030. Public green areas will be preserved and enhanced to offer easy access and a variety of experiences for all residents. All new urban development areas will contribute to a greener Aarhus with space for trees and water. In peri-urban landscapes, outdoor life will be incorporated from the start, with green connections to forests, water and natural areas. Trees on publicly owned land will be preserved as far as possible, with 10,000 additional urban trees already planted in the period 2017–2025. New nature areas are being created on formerly arable land. By 2030, the municipality has a target of 8000 hectares of forest and 4000 hectares of nature land (17% and 8.5% of the total area, respectively). New forests are designed as multi-functional areas, to help safeguard groundwater resources and water quality, store CO_2, support biodiversity and offer recreational opportunities. In choosing locations for implementing initiatives multiple factors are assessed to identify areas with simultaneous potentials for, e.g., storing carbon, supporting biodiversity and enabling the temporary retention of surface water. Prior to greening projects, local Residents' Councils, NGOs and interested citizens are invited to contribute ideas and knowledge about local conditions. When relevant, participatory processes include debates and workshops, where initiatives are discussed, evaluated and, in some instances, co-created.

4.1.3. Case Study 3—Xiamen, China

Xiamen, population 4.3 million, is located on the southeast coast of China, with a coastline of 194 km and vast coastal wetlands. But for a long time, there has been a lack of effective management, and the coastal wetlands have become severely degraded. A programme of coastal restoration was initiated by local government in the 1990s to improve the biodiversity of the coastal wetlands and the quality of life of the surrounding communities. In 2005, the Xiamen Municipal Government, in consultation with ecological experts, initiated the experimental planting of 5 ha of mangrove forest in Xiatanwei Bay, scaled up to an additional 44 ha in 2013 and a further 36 ha by 2020. This was supplemented by the rearing and release of 13 marine species such as fish, shellfish, shrimp and polychaete. The Xiaweitan Mangrove Park has become a demonstration model for carbon neutrality and forestry in China and abroad, with a two- to three-fold increase in the numbers and biomass of target species. There are now a coastal leisure and sightseeing zone, a marine ecological recreation area and a marine ecological science popularisation area, allowing citizens to fully experience the coastal ecology. Xiamen holds the first education base on the theme of "blue carbon", becoming a platform for practical education in primary and secondary schools. During the planning and the design process, the designs of the park were open to the public as part of the stakeholder engagement.

4.1.4. Case Study 4—Beijing, China

Beijing is the capital city of the People's Republic of China, with a population of 22 million. The metropolis has a chronic water shortage problem, and one important source is the Guanting Reservoir. However, the Guanting Reservoir Watershed (roughly 280 km^2) has faced serious water quality issues due to soil erosion caused by quarries, water pollution from agriculture and domestic wastes, and the degradation of riparian ecosystems. In this peri-urban NBS case study, the municipal government collaborated with the Heibei Province to initiate a restoration project in 2016 with the aim of safeguarding the

water security of Beijing through the holistic management of ecosystems in the Guanting Reservoir Watershed [67]. Actions taken include closing 30 quarries and restoring the vegetation of 128 mining sites, reconstructing 33.3 ha of wetland ponds, planting 667 ha of grass and more than 60 ha of trees/shrubs on the west bank of the reservoir, creating a buffer zone of 30–100 m around the reservoir, restoring the river habitat connectivity and natural patterns, and converting 6667 ha of croplands to vineyards. Actions were also taken to create microhabitats for wildlife. The project has led to significant improvement in water quality, better biodiversity conservation and an increased supply of ecosystem services, as well as increased income to farmers from grape production and eco-tourism. A working group was set up to develop and implement the restoration plan. The Ministry of Water Resources is responsible for coordinating actions among stakeholders, including governments at various levels, private companies and local farmers. The general public were invited to comment on the draft of plan. After its approval, the plan was carried out following a "Government and market cooperation" model, whereby an investment company was formed to manage the public and private investments to the programme and the implementation.

4.2. How Might We Manage NBS in Cities in Future

The case study examples give a flavour of what is typically carried out, using four different contexts. They do not necessarily reflect current best practice. They mostly reflect a top-down approach to the selection of the location and type of the NBS intervention, with varying degrees of consultation on the final design and implementation. The procedures used within cities for deciding how to prioritise locations for NBS interventions are rarely articulated. This may simply be because such processes are rarely recorded and discussed, and/or because many larger scale interventions are opportunistic—e.g., there is an existing obsolete infrastructure or city location that needs re-development, so the location is pre-determined. However, there is considerable scope for more strategic planning and design taking on board the framework proposed here in situations where cities have more strategic objectives, such as to plant 10,000 street trees (Aarhus) but no formal approach on how to identify locations and implement the action.

Using the approaches outlined in this paper, future planning could make use of the following steps for sustainable NBS design and implementation (Figure 3):

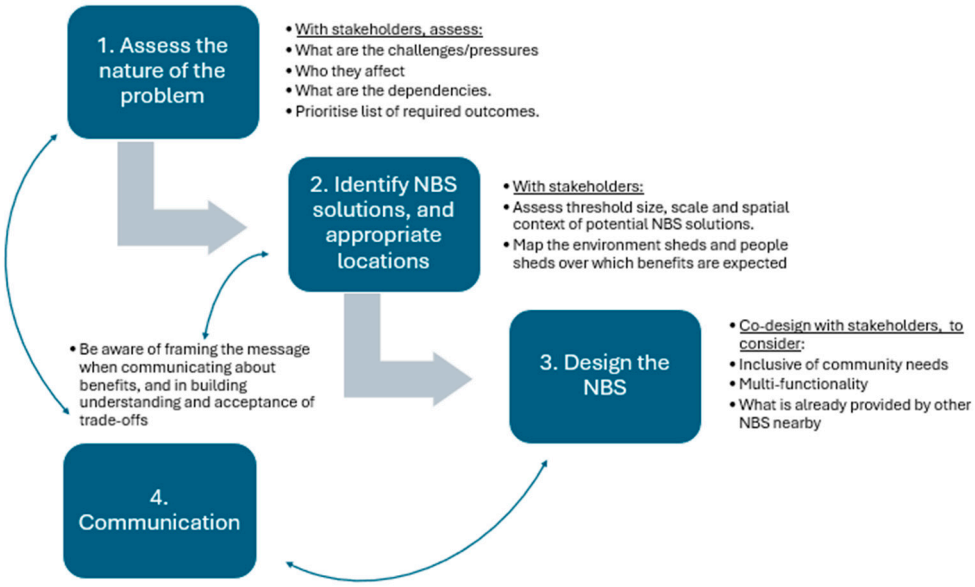

Figure 3. Decision steps and actions in planning and design of NBS to address urban challenges.

(1) With stakeholders, assess the nature of the problem. Assess the main challenges and who they affect, and the spatial scale at which they operate. This can be very localised for, e.g., noise pollution, or on a much larger scale for heatwaves. This step takes into account the people who require a solution, i.e., it factors in both pressure and demand [68].

(2) Identify the type of NBS intervention that is most useful and the likely locations, depending on the nature of the problem. This step should take account of the following issues: thresholds—is there a minimum size or extent of NBS required?; scales—over what distance or spatial area is the NBS needed: [61]; and spatial context—whether the benefits are manifested in a different location to that where the intervention takes place, e.g., for flooding [69,70]. Delineating the environment sheds and the people shed served by each intervention can help identify the locations and types of stakeholders directly and indirectly affected by (or benefiting from) the scheme. Together with information on the pressures and a priority list of primary and secondary outcomes required, this helps inform the next step of designing the NBS.

(3) Design the NBS in consultation with the full range of identified stakeholders. This process should be guided by CBD theory on how to frame the discussion and solicit input to the process—allowing genuine co-production that helps avoid many pitfalls, even in front-runner cities [71]. This process can help design the NBS to serve the primary purpose and also to ensure multifunctionality, to achieve a wider range of co-benefits. The co-production will bring in perspectives from a full range of users and facilitate finer elements of the design process, e.g., how to design play areas that are inclusive and avoid elements that inhibit full participation by particular groups, e.g., constructing them for teenagers or excluded members of society [72]. It also allows the design of elements to fulfil another key criterion for NBS, improving biodiversity, by creating a range of structural diversity, and incorporating zoning of activities to allow less disturbed areas for wildlife to flourish. The design of the NBS should also consider the functions and people sheds of other NBS nearby in the wider urban landscape to ensure a broad set of functions is provided across the city.

(4) Communication—although this is listed last, it underpins the entire process. Learning from economic theory can help improve how to communicate aims and share understanding among participants in the decision-making process. Understanding the cultural values framings of those involved in NBS design and implementation, as well as of the beneficiaries, can ensure a smoother route to communicating benefits in a neutral way which does not impose a world-view and allows decision making to be fairer, with a view to achieving a better outcome for city residents.

Following these steps would allow a more future-looking approach to NBS design and implementation, which crucially takes account of the spatial context, which is often the least-considered aspect of NBS—how high a level of service they provide in which locations, and to which residents. We recognise that implementation may be difficult since this requires co-ordination and dialogue across municipal departments and with multiple stakeholders. These implementation challenges may differ with the scale of the project. Very large projects are likely to have a sufficient budget to facilitate such dialogue and data gathering but may have too much momentum to genuinely take consultation on board. By contrast, very small projects that are largely community-driven may be rich in stakeholder involvement but lack resources or the data gathering to inform strategic planning. The challenge is how to bring these approaches to bear on the design of NBS at all scales.

5. Conclusions

In this study, we move the thinking on NBS forward to better understand the roles of people and nature in an urban setting. We propose an enhanced framework that differentiates between two dimensions of NBS. An NBS as an entity is defined by the natural and the

human-centred capital components, which collectively determine its potential to provide benefit to society. The wider NBS system then encompasses the people-environment interactions that generate the ecosystem services and the benefits, as well as the higher-level governance and management structures that condition how NBS are managed. This framework combines a detailed understanding of the components of natural and human-centred capital that underlie the environment–people interactions, and it sets it within the world of decision making and day-to-day decisions on how to make maximum use of NBS in addressing urban pressures.

Procedures to design, manage and monitor NBS are extensively documented in the literature (see for example Refs. [73,74]). However, the perspectives presented here bring a fresh insight into the way we should think about urban NBS in the future. In particular, this includes considering the spatial domains (or "sheds") of the pressures, the ecosystem services and the people who are the beneficiaries. This spatial context helps us understand the dependencies between pressure, demand and the resulting service provided by the NBS. For example, the spatial requirements of an NBS that needs to provide a quiet space where people can get away from road noise will be different from a space that is designed to provide substantial cooling on hot days to a park and to neighbouring parts of the city, or which is designed to block the movement of air pollutants into a green space. Fully integrating all three spatial elements is necessary to designing the most effective NBS.

Lastly, bringing in insights from economic theory can effectively shape the way benefits are communicated both to decision makers and the public. This should make the decision-making process smoother and help ensure decisions are made that benefit those who need the NBS most, while minimising the disbenefits or missed opportunities for others. The case studies outlined in this paper show how current practice still has room for improvement to make use of these insights. Testing the application of the framework in urban NBS planning and implementation will be an important next step. Collecting data on the human-centred capital elements in order to understand the needs and desires of beneficiaries is a particular challenge of this type of framework. However, there is increasing recognition of the affordances that NBS can provide to potential users [33], and ways to improve those interactions. This necessitates an understanding of those user needs but also of the barriers and enablers that influence their use of NBS, which in turn will allow better design and management of these spaces. New ways to capture information on these human capital elements in a way that generates transferable knowledge which can be applied in similar settings would be particularly valuable.

Author Contributions: Conceptualisation, L.J., S.A., J.L., E.B., A.J., A.T., M.H., J.Y., T.T. (Tim Taylor), B.W.W., D.F., T.T. (Thora Tenbrink), Å.S., Y.X., G.L. and M.Z.; Funding acquisition, L.J., S.A., E.B., A.J., J.Y., B.W.W., Å.S., Y.X. and M.Z.; Writing—original draft, L.J., S.A., J.L., E.B., A.J., A.T., M.H., J.Y., T.T. (Tim Taylor), B.W.W., D.F., T.T. (Thora Tenbrink), L.W.-J., S.I., Å.S., T.L., Y.X., L.L., G.L. and M.Z.; Writing—review & editing, L.J., S.A., J.L., E.B., A.T. and M.Z. All authors have read and agreed to the published version of the manuscript.

Funding: The authors of this work received funding from the following sources: The REGREEN Nature-based Solutions project (https://www.regreen-project.eu/) has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 821016 and the National Key R&D Program Intergovernmental Cooperation in International Science and Technology Innovation from Ministry of Science and Technology of China under grant agreement No 2021YFE93100. Authors also acknowledge funding from: the UK RECLAIM Network Plus project (EP/W033984/1), funded by the UKRI (EPSRC, NERC, AHRC), NERC funded Greencities (NE/X002772/1) and Defrag (NE/W002892/1), and National Natural Science Foundation of China (42271299).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: No new data were created or analysed in this study. Data sharing is not applicable to this article.

Acknowledgments: We gratefully acknowledge additional input from James Miller, Bettina Lerche, Lene Vinther and Andreas Tuerk.

Conflicts of Interest: The authors declare no conflicts of interest.

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