Rewilding the built environment: a resilient response to different crises

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Abstract
Society continues to face many crises, from climate change, loss of biodiversity and air pollution to the pandemic, with associated impacts to human health and wellbeing. The built environment plays an important role in both mitigating and adapting to these impacts and in safe-guarding citizens. The presence and access to green spaces in the built environment plays a fundamental role in citizen’s ability to cope with adversity of different kinds and scale, while in itself supporting biodiversity. This paper aims to (1) synthesize knowledge about the diverse role that green spaces, and by extension the rewilding of our built environment, play as part of a resilient society and built environment and (2) the specific conditions and characteristics of green spaces and the built environments to maximize their benefits, while avoiding unintended consequences. This is done through a systematic literature review to present existing knowledge about the role of green spaces in a resilient built environment and society, followed by a qualitative content analysis that identifies the conditions and characteristics of green spaces as resilient solutions. Findings highlight the importance of the diversity of green space provision in type (e.g., ecological corridors), scale (e.g., community gardens, green roofs and walls), and location (e.g., parks, forests), and that they can support social inclusivity, community resilience and wellbeing. Furthermore, findings highlight that green spaces need to be designed in such a way that they (1) support biodiversity, (2) are interconnected with the context, (3) accessible and (4) appealing for citizens to protect and appreciate them.

Keywords: built environment, resilience, sustainability, green infrastructure, re-wilding, greening.

PEER-REVIEWED ARTICLE • RESILIENCE

Introduction

Globally, many citizens are suffering the impact of multiple crises, e.g., global economic recessions, energy crisis, war, food insecurities, basic services price inflation, climate crisis, etc. (Wheeler, 2022), affecting infrastructure and ecosystem functions, political cohesion, and society's health and wellbeing (Schrecker, 2012). The combination of multiple impacts can lead to direct impacts (e.g., biodiversity loss) or indirect consequences, where particular urban areas are excluded due to environmental degradation (Shrubsole *et al.*, 2015; Damm *et al.*, 2019). Resilience in the built environment can be defined as the combination of physical built infrastructure (public buildings, residential parks, dwellings), non-material built infrastructures (system of political power, regulations, councils), and the community characteristics (social norms, culture, common interests, collective actions) that empower society to mitigate and overcome the impact of different disturbances while strengthening them during the recovery process (Hassler and Kohler, 2014; Cerè, Rezgui and Zhao, 2017).

Several studies highlight the potential of the built environment in both mitigating and adapting to crises and in safe-guarding citizens (Hassler and Kohler, 2014; Sharifi, 2016; Cariolet, Vuillet and Diab, 2019; Yang *et al.*, 2021; Castaño-Rosa *et al.*, 2022). For example, Castaño-Rosa et al. (2022) identify the provision of green and healthy, adaptable, and equitable and inclusive infrastructures as key strategies to promote resilience in the built environment; Yang et al. (2021) discuss the need to develop well-mixed urban zoning, reducing commute time and promoting walking and biking behaviours; and Hassler and Kohler (2014) conclude flexible collaboration between different actors (i.e., citizens, policymakers, and different stakeholders) through a democratic process as a basis to promote resilience in future scenarios. The implementation of green infrastructures in cities (or rewilding) has become an effective strategy to bring nature (and its benefits for society) back to the urban environment (Lee, Jordan and Horsley, 2015; Kabisch *et al.*, 2016; Grădinaru and Hersperger, 2019; Jerome *et al.*, 2019; Lehmann, 2021). There is not a common definition of the concept of 'rewilding' the city, but in this paper the term is defined as the combination of actions to implement green spaces with multiple species in the urban environment in a way that support wildlife, biodiversity and ecosystem functionality (Danford *et al.*, 2018).

In the light of the climate and biodiversity crises, the European Commission has developed a common strategy on green infrastructure development to promote and support a successful and effective implementation of green infrastructures (European Commission, 2013). Furthermore, as one of the European Green Deal's pilar (European Commission, 2019), the European Commission has approved the biodiversity strategy for 2030 (European Commission, 2021) aiming to protect nature and reverse current ecosystems degradation. In the existing literature, nature-based solutions (NBS) have been coined as an 'umbrella' term covering green spaces, infrastructure, ecosystem-based mitigation, etc. (Nature, 2017), and it has been shown to be an effective solution to contribute to urban resilience (Bush and Doyon, 2019). The International Union for Conservation of Nature define NBS as "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" (IUCN, 2020). Thus, this paper will use 'green spaces' to refer to the implementation of all kinds of green spaces, including 'NBS' and 'rewilding' the city. Researchers across the world have shown the potential benefits of green spaces for society, such as increase of biodiversity, functional diversity, animal productivity (Chausson *et al.*, 2020), social capital (Tidball *et al.*, 2018), health and wellbeing (e.g., more people doing outdoor activities, reduced air pollution) (Frumkin *et al.*, 2017). Connection to green spaces also promotes the effectiveness of treatment and management of disability and illnesses, such as depression (Hartig *et al.*, 2014), strengthen the immune system (Roslund *et al.*, 2021), addressing environmental injustices, inequitable exposure and access to environmental goods (Stewart, 2020). However, urban redevelopment strategies through the implementation of green spaces can also create contradictory results, such as gentrification (also, known as eco-gentrification, green or environmental gentrification (Checker, 2011)); redevelopment of abandoned spaces or poorer neighbourhoods with green spaces may lead to an increase in property values, causing the displacement of the less well-off citizens to more affordable, but excluded, areas (Wolch, Byrne and Newell, 2014). Thus, there is a need to consider potential unintended consequences when conducting the redevelopment of existing areas with green spaces (or without).

There are several frameworks to support the implementation of green spaces as well as assess their effectiveness (e.g., Zölch et al. 2017; Simonson et al. 2021; Raymond et al. 2017; Lee, Jordan, and Horsley 2015; Jerome et al. 2019; Dorst et al. 2019; Di Sacco et al. 2021; Calliari, Staccione, and Mysiak 2019; Bush and Doyon 2019; IUCN 2020), with all of them considering *multi-form* (meaning different forms of nature), *multi-function* (i.e., benefits to society), *multi-discipline* (i.e., collective action at different levels), and *place-based* (not universal but socio-spatial context based) as key design principles to promote urban resilience, as defined by Dorst et al. (2019). For instance, the Urban Nature Futures Framework (UNFF) developed by Mansur et al. (2022) is based on three perspectives to support the management of nature in cities through the development of different scenarios: i.e., the Nature for Nature (nature dominates the city), Nature for Society (designed with people to enhance use), and Nature as Culture (solutions focus on promoting cultural experiences of nature). Through the analysis of different solutions of green spaces in 11 European cities, Frantzeskaki (2019) define seven lenses for the implementation of green spaces in cities highlighting its complexity and the need for multiple disciplines to come together in the design process. Similarly, O'Neil and Gallagher (2014) define 'a good-quality green network' framework through a set of principles, highlighting *proximity*, *biodiversity*, *linkage*, *cooling*, *flooding risk* and *quantity* as the core principles to promote green space network quality. However, these frameworks were defined by considering single aspects instead of reflecting on the influence of other aspects, such as multiple crisis impacts, the role of community practices, inclusion of non-human elements, management of green spaces, interactions across scales and different kind of greening, etc. Furthermore, there are potential unintended consequences that are not explicitly addressed in the implementation of green spaces in the built environment, jeopardising their effectiveness (Bush and Doyon, 2019). These potential unintended consequences could be:

- *temporal* (solutions, or decisions made, implemented at one time can create negative effects in the future; this requires long-term perspectives) (Chelleri *et al.*, 2015);
- *spatial* (everything is interconnected, meaning that (1) solutions implemented in one location may negatively affect other locations, and (2) actors at different scales, e.g., micro-, meso-, and macro-scales, are interconnected) (Chelleri *et al.*, 2015; Turkelboom *et al.*, 2018);
- *functional* (one solution's function can alter the functions/features and, consequently, the effectiveness of other solutions) (Turkelboom *et al.*, 2018);
- *social inequity* (even distribution of green spaces and their associated benefits and costs) (Parris *et al.*, 2018);
- *ecological exclusion* (different species' coexistence means enabling different environmental conditions and management to avoid exclusion/extinction) (Kabisch *et al.*, 2016).

In summary, the existing frameworks mentioned above focus mainly on developing resilient green spaces, infrastructures, etc. and/or assessing their effectiveness instead of understanding how to implement them in order to promote resilience in the built environment and society in general. Thus, it remains unclear how green spaces need to be designed to specifically promote resilience to several crises impacts in the built environment while avoiding unintended consequences (or trade-offs), e.g., avoiding biodiversity degradation, social exclusion, gentrification, inequality, etc.

This study aims to contribute to this knowledge gap by providing a better understanding about the role of green spaces as part of a resilient society and built environment, and what the key conditions are that have been proven effective, particularly as a response to multiple crises and supporting inclusive design. Hence, this paper focuses on the following research question *'what are the key conditions to rewilding as part of a resilient society and built environment to multiple crises?'*

This article is structured as follows: first, the methods used to collect and analyse the data are explained. Then, results are presented highlighting how green spaces can provide resilience to multiple crises, and their key conditions for resilience discussed. This is followed by a concluding summary and reflections for further research.

Methods and data analysis

To identify key conditions to design green spaces as part of a resilient built environment to multiple crises, a systematic literature review was conducted, identifying main solutions in the built environment (see Figure 1). Then, key conditions for resilience were investigated and categorised through a qualitative content analysis. Figure 1 shows graphically the research process followed in this study.

A diversity of green spaces can support social inclusivity, community resilience and wellbeing.

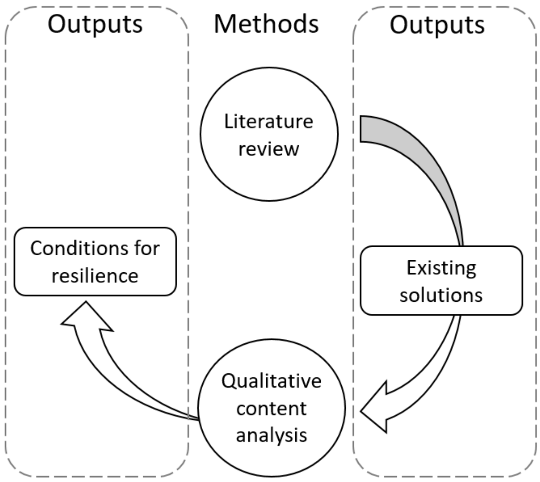

Figure 7. Research process.

A systematic literature helped to collect evidence of existing solutions and summarise existing knowledge through a clear protocol (Gough, Oliver and Thomas, 2017). To conduct the literature review, the protocol defined by Xiao and Watson (2017) was used, defining three main steps: (1) searching for articles according to the inclusion criteria; (2) screening of the sample by using exclusion criteria; and (3) studying the final sample.

Figure 2 graphically depicts the literature review protocol defined for this study. To guarantee peer-reviewed material, the source of data used was ‘Web of Science’. In the first step (identification), a search was conducted using the keywords ‘built environment’ and six earlier identified crises, i.e., ‘climate crisis’, ‘housing crisis’, ‘pandemic crisis’, ‘financial crisis’, ‘demographic crisis’, or ‘digital crisis’. The selection of these keywords is based on Castaño-Rosa et al. (2022), which sets out the rationale for the six crises and who highlighted that green infrastructure is one of the key solutions to achieve resilience in the built environment to multiple crises. Furthermore, the search was limited to English and peer-reviewed articles that were published in the last 10 years, gathering the most recent solutions in the built environment. In the first step, the search gathered a total of 1808 papers, based on the content of the title, abstract and keywords. The sample was reduced to 1183 papers after removing duplicate results. In the second step (screening), the exclusion criteria were implemented by using the keywords ‘green spaces’ and ‘green infrastructure’ in the abstract; note that both terms were selected based on the common terms used by the European Commission to define green infrastructure strategies (see Introduction section, page 2). Therefore, the final sample of articles included in this study consisted of 43 peer-reviewed articles.

It is worth acknowledging that, the above inclusion and exclusion criteria (i.e., keywords, publication year, language, peer-reviewed articles), might be one limitation of this study since other solutions are not included in academic articles. Finally, to identify the interconnections between the different solutions, a qualitative content analysis was conducted by following Schreier (2012). Qualitative content analysis was used to enable categorisation and identification of solutions (after Schreier (2012)). The qualitative content analysis (after (Tuomi and Sarajärvi, 2017)) consisted of the following three steps: 1.) independent analysis of the five defined categories by two researchers; 2.) defining of categorises and their interconnections through an iterative process (of both collaborative and individual reflection); and 3.) key characteristics were mirrored against multi-level perspectives (i.e., macro, meso, and micro levels (Geels, 2004)).

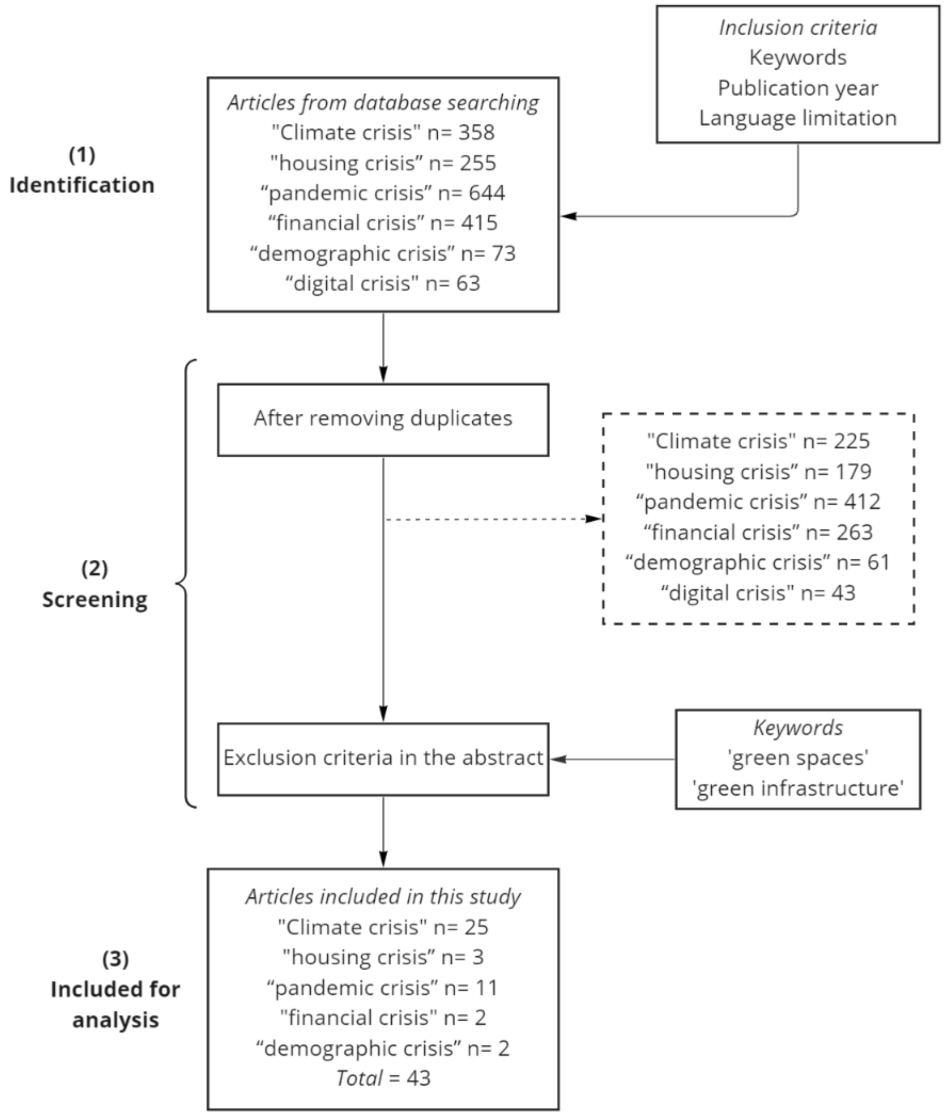

Figure 8. Scoping review protocol.

Results and discussion

Reviewed literature was mostly conducted globally. However, studies on the climate crisis were mainly based in Central and South Asia (23 out of 25), representing those areas most affected by the impact of climate change. This was followed by pandemic crisis, where studies investigated the role green spaces played in supporting mental and physical wellbeing during COVID-19. Literature on housing, financial and demographic crises investigated the role of green spaces to promote housing market and economic recovery in Central Europe. In the end, a total of 17 solutions, clustered into 5 groups, were identified in the reviewed literature, and discussed through qualitative content analysis in the section below.

Analysis of existing green spaces solutions

A total of 17 solutions categorised into five main groups were identified from the literature review as resilient built environment solutions to a diversity of crises (i.e., 'climate crisis', 'housing crisis', 'pandemic crisis', 'financial crisis', 'demographic crisis', or 'digital crisis). These solutions are listed from macro to micro scale in five groups (1) urban environment restoration; (2) urban green spaces; (3) domestic green spaces; (4) green roofs and (5) vertical green. Below, the different solutions, characteristics, and key considerations for implementation as part of a resilient built environment are presented.

1). Urban environment restoration focuses on recovering (restoring) existing natural habitats in the urban environment. This includes river restoration, ecological restoration, and wastelands as biodiverse areas – all unfolded in more detail below.

- *River restoration* refers to all the practices and measures (e.g., spatial, physical and management) aiming to restore the natural state and functions of the river system (ECRR, no date). A successful intervention can support flood control, recovery of hydrological functions (i.e., infiltration and retention of water), urban heat island mitigation, environmental and social benefits, such as biodiversity restoration (Veról *et al.*, 2019). *Deculverting* is an effective strategy for river restoration which consists of opening covered watercourses (e.g., rivers) to restore them to more natural conditions (Eisenberg and Polcher, 2019). The reviewed literature showed the potential of river restoration in creating recreational areas and sustainable transport (i.e., pathways for pedestrian and cycling), enhancing ecological and societal benefits (e.g., community engagement), and making existing urban areas more appealing for people to protect and maintain them (Wild *et al.*, 2011; Dinić-Branković and Marković, 2021).
- *Ecological restoration* refers to any practices that aim to recover, renew and restore an ecosystem that has been degraded, disturbed, damaged or destroyed (by human action) (Aradottir and Hagen, 2013). The reviewed literature listed actions such as rock detection structures (RDS) to restore dryland water run-off, which would otherwise contribute to drought, erosion and need restoring to contribute to flood mitigation and to store, filter and transform nutrients (Gooden and Pritzlaff, 2021). Other actions are managed aquifer-recharges (MAR), meaning a natural treatment and transportation of water of existing natural wetlands (Rahman *et al.*, 2013). However, ecological restoration practices require technical feasibility, and economic and financial viability supported by public policies and monitoring instruments (Bustamante *et al.*, 2019).
- *Wastelands,* as biodiverse areas, are neglected and overgrown areas of previous industrial or other use (Bhunia *et al.*, 2021). In urban areas, wastelands have a huge potential to contribute to biodiversity conservation, i.e., home to a large number of species, floristic diversity (Bonthoux *et al.*, 2014), and even mitigate gentrification issues (Draus *et al.*, 2020). Location, area size, age, soil, microclimate, vegetation structure and animal communities, and human and domestic animal disturbances are the main factors to bear in mind when considering preservation or creation of wastelands in urban planning developments (Bonthoux *et al.*, 2014).

2). Urban green spaces are mainly public spaces to develop, individually or in group, recreational activities that, due to the ecosystem configuration, provide space to relax, do physical activities, restore mentally and physically, socialise, etc. (Vidal, Barros and Maia, 2019). Main typologies identified from the reviewed literature included green corridors, urban prairies, urban forests, constructed wetlands, green boulevards, arboretums, residential neighbourhood parks, edible urban commons.

- *Green corridors* are natural or semi-natural connected open spaces within or outside cities that create a green network, provide ecological, environmental, cultural and recreational benefits (Aman *et al.*, 2022). Green bridges are highlighted as one of the most effective types of green corridors to connect green habitats that would otherwise be fragmented by, e.g., roads or train tracks (Plaschke *et al.*, 2021). To avoid unintended consequences such as ecological and biodiversity destabilisation, use of local regeneration materials, natural processes, and effective management decisions are important to include (Simonson *et al.*, 2021).

- *Urban prairies*, i.e., vacant urban lands reverted to green spaces, support wildlife and biodiversity conservation (Reynolds *et al.*, 2020). Vegetation characteristics are crucial in the hydrological performance of green spaces and increases with a combination of species in comparison with single-plant plots (Yuan, Dunnett, and Stovin (2017).
- *Urban forests* are green spaces with different typologies of trees in urban areas with spaces for multiple uses, recreation and environmental protection (Corona *et al.*, 2012). Central Park in Manhattan, New York, is the most famous example of the implementation of urban forests in high-density urban environments with a representation of its potential to address environmental issues such as air pollution, wastewater management, biodiversity conservation, etc.
- *Constructed wetlands*, or *treatment wetlands*, are engineered systems composed of vegetation, soils, and related organisms, to provide treatment of stormwater and wastewater from industrial, municipal and domestic activities through natural processes (Vymazal, 2011). The reviewed literature showed the potential of constructed wetlands to contribute to climate resilience, ecosystem and biodiversity restoration, mental wellbeing, improved air quality and urban heat island improvement (Gorgoglione and Torretta, 2018).
- *Green boulevards*, *green streets* or *green alleys*, consist of the integration of vegetation (e.g., trees, shrubs, perennials, grass), soil and permeable pavements close to and between roads to manage stormwater and reduce flood risk. Unlike conventional streets that are mainly road vehicle-oriented, green boulevards are designed following pedestrian-oriented approaches to prioritise a safe and healthy environment (Im, 2019), connecting with nature. Consequently, they encourage active mobility and other healthy behaviour in high-density neighbourhoods (Mitra *et al.*, 2020). Existing streets/alleys can be transformed through the implementation of green areas providing societal benefits through the connection with nature and the creation of a more resilient built environment (Newell *et al.*, 2013).
- *Arboretums*, or *botanical gardens*, are places in the urban environment where different trees and plants are cultivated for educational and scientific purpose; the reviewed literature showed its potential for mental health recovery, leading botanical gardens to be considered as a new type of restorative environments (Hartig, 2004; Carrus *et al.*, 2013). They provide the opportunity to spend time in the nature within dense urban environments promoting psychological and physical benefits, conservation of plants, knowledge and cultural exchange and social interactions (Carrus *et al.*, 2017).
- *Residential neighbourhood parks* can be large spatial areas combining different uses and functions (e.g., sport fields, space for outdoor concerts, etc.) or small green spaces designed for a specific function (e.g., playground for children) (Eisenberg and Polcher, 2019). Access to outdoor green spaces offers numerous mental and physical health benefits, providing opportunities for physical activity and social interaction (Ahsan, 2020). However, special attention is needed to the potential impacts of urban green parks on house prices, which usually tend to increase when green spaces are nearby; this triggers gentrification issues (Chen *et al.*, 2022)
- *Edible urban commons* include community gardens, rooftop agriculture, and urban and peri-urban farms, and provide multiple functions/benefits to society, such as food security, microclimate regulation air, carbon storage, space for relaxation and recreation, etc. (Reynolds *et al.*, 2020). During the pandemic, the resilience potential of edible urban commons

highlighted healthy benefits (e.g., enhanced immunity), self-sufficiency (in terms of food, water, and energy), social capital (people meeting and interacting with each other), and the shared economy (i.e., sharing the harvest, plants, and seeds with the community members) (Sardeshpande, Rupprecht, and Russo, 2021).

3). Domestic green spaces are those implemented at the housing block level or individual dwelling and include gardens and green courtyards, urban lawns and biophilic design principles.

- *Gardens and green courtyards* are a private adjacent area to a dwelling or housing block (Cameron *et al.*, 2012), which provide health benefits to the residents and, if designed appropriately, can provide thermal comfort and energy consumption reductions by sheltering buildings. Depending on the city, domestic gardens can represent up to 36% of the urban area, but this can be unevenly distributed between and within cities (Cameron *et al.*, 2012). Considering the multiple benefits for society's health and wellbeing from domestic gardens, this uneven distribution of private green spaces raises the question about environmental justice (Wolch, Byrne and Newell, 2014). During the COVID-19 pandemic, the potential benefits of domestic gardens was highlighted: they provide space for recreational and physical activities; positively affect mental wellbeing, and even economic and environmental benefits when converted into a vegetable garden (which creates small-scale natural resources promoting self-sufficiency and consciousness at the household level) (Sofo and Sofo, 2020). Furthermore, implementing sloped garden harvesting, i.e., collecting rainwater in underground water tanks through a raised platform for further purification and filtration depending on the use (Pala *et al.*, 2021), has been shown as an effective solution to reduce water consumption, e.g., up to 30% in comparison with the conventional water supply systems, as this high quality water can be used for washing, watering the garden, etc. (Moshfika, Biswas and Mondal, 2022), and ideally not for low-quality uses such as toilet flushing.
- *Urban lawns*, often found in the front yard or backyard of houses, provide space for recreational purposes, and if designed well, urban lawns play an important role in urban heat island mitigation, carbon sequestration and biodiversity conservation. For example, more voluminous lawns, including trees, notably increased the cooling effect in Montreal (Canada); mainly due to solar radiation protection (Francoeur et al. (2021). When combined with urban drainage system (e.g., a rain garden), through the use of vegetation and permeable surfaces and soils, it also addresses flooding issues, reduces water pollution, and enhances biodiversity (Casal-Campos *et al.*, 2018). However, to avoid potential unintended consequence, special attention should be paid to design (not just grass surfaces) and maintenance, as otherwise urban lawns contribute to carbon emissions (Reynolds *et al.*, 2020).
- *Biophilic design principles* are a design approach that aims to connect residents with nature (Wijesooriya and Brambilla, 2021), for instance, providing direct visual and physical contact with nature, using natural materials, increasing daylight, including indoor greenery, etc. (Andreucci *et al.*, 2021). Visual connection to nature can reduce stress, improve mood and relaxation (Catherine O. *et al.*, 2014) and combined with physical access helps to reduce blood pressure and improve mental health and sleep, and encourages physical activity (Tabb, 2020).

4). Green roofs, generally classified into intensive (i.e., greater depth allows more intensive planting and use by people) and extensive green roofs (shallow substrate with planted sedum that cannot be walked on). Green roofs should consist of native local plants, which can support unfavourable climatic conditions, a drainage layer (e.g., soil and drainage layer) and thermal insulation on rooftops

(Cascone, 2019). At the building level, green roofs have the potential to improve building energy efficiency, e.g., cooling energy demand reduction of up to 15.2% in comparison with conventional solutions (Yang *et al.*, 2015). At the urban level, they contribute to urban heat island mitigation and outdoor environmental quality improvement (i.e., reduction of carbon emission, sulfur dioxide and nitrogen oxides) (Ziogou *et al.*, 2018). However, the main barrier to promote their installation in single-family buildings is the high installation costs in comparison with any energy cost savings. Key conditions for green roofs to promote resilience are (1) using local plants (which are able to support the local climatic conditions and reduce maintenance) and (2) making the solution cost-efficient and affordable (i.e., installation and maintenance costs should be economically feasible for either public or private investors) (Ziogou *et al.*, 2018). For these and other reasons, light weight and low maintenance (extensive) green roofs are the most common, and effective, solution towards resilience (Cascone, 2019), though these cannot be used as recreational space.

5). Vertical green consist of green walls (i.e., any kind of living wall systems including, for example, free standing living walls or mobile greening) and green facades (including both ground based and wall-based vertical greening systems) (Medl, Stangl and Florineth, 2017). Vertical greening is a suitable solution to increase vegetated surfaces in urban environments, however, it requires the selection of suitable plants according to the climatic characteristics of the context and purpose (Safikhani *et al.*, 2014). If well implemented, vertical greening has abundant benefits for the environment and society's wellbeing, e.g., it promotes the microbiological diversity restoration in cities, whose microbiological particles in the air circulating through green walls and façades have been seen to positively affect skin health (Soininen *et al.*, 2022). It also has important wall surface and spatial cooling potential, contributing to urban heat island mitigation, energy savings and indoor thermal comfort (Medl, Stangl and Florineth, 2017). Note that wall based vertical greening systems that require energy use for water and nutrient circulation are maintenance and energy-intensive and vulnerable to failure (Gunawardena and Steemers, 2020); this was however not explicitly mentioned in the systematic literature review, but would clearly affect the resilience of the system, and hence this solution in itself.

Key conditions for resilience of green spaces to different crises

As explained above, 17 solutions were identified from the literature review. However, there is a need to understand how green spaces need to be designed to enhance resilience in the built environment and our society in general, avoiding unintended consequences. As previously mentioned, examples of unintended consequences could be exclusion of people through gentrification, or an increase in carbon emissions if ill-designed, or where one species is supported at the expense of others, or negative impacts in the future due to out-of-context solutions.

Based on the reviewed literature, this section uses the four key principles for the implementation of green spaces as defined by Dorst et al. (2019), i.e. *multi-form*, *multi-function, multi-discipline,* and *place-based*, and to make it more accessible and understandable for different stakeholders, these were adapted into four key conditions for resilience of green spaces to different crises impacts, which are:
(1) (Bio)diversity (the potential of different forms of nature to promote resilience either as a whole or individually; *multi-form principle*);
(2) (Inter)connection (socio-spatial context and functions matters play a key role in a successful and long-lasting implementation of green spaces, and so resilience promotion; *place-based principle*);
(3) Accessible (the implementation of green spaces for humans and non-human elements, equally distributing material and immaterial public resources across society; *multi-function principle*);

(4) Appealing (covering different actors' needs and expectations so that they want to protect and appreciate them; *multi-discipline principle*).

Furthermore, the potential unintended consequences associated with the implementations of green spaces identified in the literature (i.e., temporal, spatial, functional, social inequity, species exclusion) are discussed. Table 1 summarises the key conditions and considerations for the design and transformation of green spaces as part of a resilient society and built environment to deal with multiple crises impacts, as well as the potential unintended consequences identified form the literature.

1. (Bio)diversity

Biodiversity refers to a variety of living species in a particular habitat (National Geographic Society, 2022), and is vital for all life (human an non-human) on Earth. For humans plays an important role in ecosystem functions goods, and services (i.e., clean air, water, etc.), and, consequently, in promoting healthy and resilient built environments (Romanelli *et al.*, 2015). Diversity of fauna and flora does not only support different species but also increases the human sensory experience (Elands *et al.*, 2019), which can be achieved with the provision of a variety of green spaces and landscaping as discussed earlier, e.g., roof gardens, residential parks, urban forest, wastelands, green boulevards, urban lawns, arboretums, etc., including a wide variety of vegetation, such as trees, shrubs, mushrooms, berries, aquatic plants (seaweed), etc. Two key aspects for resilience highlighted in the reviewed literature is the need to consider (1) indigenous plants with seasonal interest (e.g., deciduous trees and vines, especially facing East and West, can provide shade in the summer and allow light in the winter), and (2) low-maintenance wildlife habitats, and whenever possible, to harvest and recycle rainwater for irrigation (Vymazal, 2011; Safikhani *et al.*, 2014; Yuan, Dunnett and Stovin, 2017; Parris *et al.*, 2018; Ziogou *et al.*, 2018). Instead of combining species from different contexts (habitats), indigenous plants should be used, ensuring that the whole is functioning (i.e., avoiding *functional consequences*) (Turkelboom *et al.*, 2018), as well as mitigating the risk of extinction (i.e., avoiding *species exclusion consequences*) (Kabisch *et al.*, 2016). Furthermore, mature nature, and mature trees and landscape habitats in particular, is irreplaceable due to all the benefits for biodiversity and ecosystems they harbour, such as carbon sequestration, visual amenity and climate change mitigation and adaptation (Hartig *et al.*, 2014; Kabisch *et al.*, 2016; Frumkin *et al.*, 2017; Nature, 2017; Mansur *et al.*, 2022), meaning that society should not demolish them, even if they are replaced with younger specimen (avoiding *species exclusion consequences*).

The reviewed literature also highlighted the importance of the provision of restoration and preservation of habitats for non-human elements, such as fish, amphibians, reptiles, mammals and birds (Aradottir and Hagen, 2013; Veról *et al.*, 2019). For example, ground or roof areas that are undisturbed for humans, such as wildflower areas, bird, bat and bee boxes, animal feeding stations and water elements, under appropriate environmental conditions with reduced night-time lighting and facing downwards to protect nocturnal species (Wild *et al.*, 2011; Bustamante *et al.*, 2019); enabling interconnection and coexistence between humans and non-humans (avoiding *spatial consequences*) (Chelleri *et al.*, 2015). The role of wetlands in mitigating the impacts of flood, drought, and fire in a variety of US regions, highlighted the need to restore, maintain and even create wetland habitats as a low-cost solution to mitigate natural hazards impacts (Fairfax and Whittle (2020). Moreover, urban areas are usually around 4-5°C warmer than the surrounding countryside, creating an urban heat island effect, exacerbating hot summer temperatures (Mohajerani, Bakaric and Jeffrey-Bailey, 2017). Thus, it is important to provide shade by using trees and evaporative cooling from low-height vegetation (i.e., grass, row of bushes), green roofs, and vertical green, which can reduce local temperatures by 2-3°C (Yang *et al.*, 2015;

Medl, Stangl and Florineth, 2017; Francoeur *et al.*, 2021). Low-time and the cost of maintenance tasks must be prioritised, otherwise the space may not be sustainable in the long-term (avoiding *temporal consequences)* (Chelleri *et al.*, 2015)**.**

2. (Inter)connection

Interconnection in this paper refers to the need (1) to mitigate habitat fragmentation by promoting connection between green spaces at different scales (i.e., from roofs to domestic gardens, residential parks, urban forests to green corridors) (Allen, 2012) and (2) to increase human contact with natural environments (known as biophilia – see earlier) (Wijesooriya and Brambilla, 2021).

Fragmentation of the natural environment should be avoided and, ideally, urban nature should be part of a wider green areas, where urban and wild nature are connected to each other and to other and surrounding green spaces (Frantzeskaki, 2019). However, this requires collaboration between private and public actors to ensure that functions, ecological processes and wildlife habitat quality are protected (avoiding *social inequity consequences*) (Allen, 2012). The reviewed literature showed green corridors as an effective solution to address habitat fragmentation threatened by continuous urban development, and a crucial component for the overall system's health, species survival, and climate change mitigation (Aman *et al.*, 2022). Green corridors often include pedestrian or cycle routes and recreation areas, connecting other green spaces in cities. Green corridors must be designed in a way that cool air flows from rural areas into the city supporting urban heat island mitigation (Simonson *et al.*, 2021). Another solution from the literature was the use of green bridges to connect green habitats that would otherwise be fragmented, mitigating the impact of the fragmented urban environment (i.e., roads, trains, etc.) on wildlife (i.e. avoiding *spatial, functional and species exclusion consequences*) (Plaschke *et al.*, 2021).

New urban (re)development should consider existing context characteristics and prioritise previously developed land with low ecological value and further enhance its functions and role in the surroundings (Raymond *et al.*, 2017; Eisenberg and Polcher, 2019). Note that special attention should be paid to the unintended consequences associated to the revitalisation of public abandoned areas with green spaces and/or residential parks, because land value increase can trigger gentrification and displacement of most vulnerable residents (e.g., low-income households), similar to the situation experienced in the High Line Park revitalisation project in New York in 2009 (i.e. *functional and social inequity consequences must be avoided*) (Lang and Rothenberg, 2016).

Human connection to nature (i.e., biophilia) increases citizens' wellbeing, both when people are in contact with nature visually and when they have physical access to the natural environment (Andreucci *et al.*, 2021; Wijesooriya and Brambilla, 2021). At the building scale, using indoor plants has multiple benefits for mental health and improves indoor air quality, reducing the risk of overheating in summer time (Africa *et al.*, 2019). Furthermore, building users should be able to furnish and adjust spaces in such a way that they can maximise the views and visual outdoor connections to nature and trees. There is a connection between visual outdoor connections and noise pollution, in particular, residents in Ghent (Belgium) with a view of vegetation through the living room window reported a strong reduction in noise annoyance (Van Renterghem and Botteldooren (2016). Other studies investigate the restorative potential of vegetation, and report improvements in performance (attention) and reduction of stress when there is good visual connection with natural elements (Van Renterghem (2019).

There is the need to adopt, through democratic, participatory processes, a holistic approach that ensures the needs of humans and non-human elements are met fully.

3. Accessible

Accessibility is defined in this paper as the possibility to connect with nature within your own home and neighbourhood and in the city, equally distributing material and immaterial public resources across society – a key component for social cohesion (positive social experiences that support relationships and a sense of community and/or belonging) (Schiefer and van der Noll, 2017). Local circumstances (e.g., topography, root characteristics, surrounding land use, and underground uses) need to be considered (*avoiding spatial and social equity consequences*). For instance, having roadside trees and grass within the neighbourhood can help reduce stress levels, but it is important to ensure that trees do not hinder wind dispersal of pollutants at street level by allowing for at least 1.5 m between crown and building façade, and 5-8 m between trees (Eisenberg and Polcher, 2019). The reviewed literature highlighted that access to external green spaces and presence of biodiversity support social interaction and, consequently, social cohesion and social capital (i.e. making resources available through social networks) (Jennings, Johnson Gaither and Gragg, 2012). Equal access to green spaces is important to enhance everyone's health and wellbeing, and not just the privileged or able-bodied people (Wolch, Byrne and Newell, 2014). Thus, green spaces should be placed ideally within no more than a 15-minute walk from housing developments; literature showed that walkable neighbourhoods with connection to green spaces encourage people to go out and socially interact with each other, supporting a sense of community (French *et al.*, 2013). Physical connections need to be easy and safe for a diversity of users, e.g., provision of clear signage, safe crossings and several entrances and access ways. Furthermore, level surfaces or ramps with low thresholds and paths that are accessible to people with prams, older people, etc. are also essential to make green spaces accessible (Lee, Jordan and Horsley, 2015). In the end, it is essential to consider that individuals and social groups (e.g., children, young people and the elderly) have different interests and needs, and these need to be taken into account to design diverse green spaces (avoiding *social inequity consequences*). For example, play areas for children with green space presence have the potential to reduce the risk of psychiatric disorders (Kristine *et al.*, 2019), wider grassed areas for more dynamic activities can promote adopting and maintaining healthy behaviours (Mitra and Manaugh, 2020), and more intimate and sheltered spaces can contribute to attention restoration and stress relief (Van Renterghem, 2019).

4. Appealing

Appealing in this paper means the need to promote good relationship between citizens and their natural environment, understood in the reviewed literature as biocultural diversity (Maffi and Woodley, 2012). Biocultural diversity can be considered a useful tool to understand human-nature interactions based on the relationship between biodiversity and culture, and its role in promoting and maintaining green spaces, e.g., high cultural diversity combined with high biodiversity can make a green space more inclusive as this means that it has been co-developed within the community (addressing *social inequity consequences*). This co-development process promotes knowledge exchange among the communities and people involved, and brings up the feeling of ownership and respect for biodiversity (Vierikko *et al.*, 2016). Literature showed that one key aspect to promote the feeling of ownership is related to the ability of users to adapt and change the social use of green spaces (so that different communities' needs are met fully), as well as being able to use it at different times *(necessary to avoid temporal and functional consequences)*. Examples of such spaces include different recreational green spaces and vegetation for children, youth, and older adults (e.g., integrated play areas, benches to sit, walk a dog, etc.) (Loughran, 2018). A common urban green space where residents can grow food and sharing (e.g., edible urban commons, community gardening) helps also promote a sense of community among residents, while increasing people's self-sufficiency and potentially reducing carbon emissions and costs (Sardeshpande, Rupprecht and Russo, 2021). However, spaces need to be designed in a way that encourage people to use them and spend time, e.g., benches and picnic tables, and pedestrian paths and access ways that are safe and sufficiently wide for people to meet and spend time while others can pass. It is also important that these spaces can provide sunlight and protection from noise, wind, sun and rain. The community play an important role in the promotion and acceptance of social and environmental projects (Frantzeskaki *et al.*, 2016), highlighting the need for understanding local needs, knowledge, and previous negative experiences with similar projects as this can create a the lack of willingness to take responsibility for the protection and maintenance of the space, jeopardising its long-term sustainability (Thörn and Svenberg, 2016). In this respect, the reviewed literature showed the need to consider that urban green spaces have different cultural values depending on the group of people that use the spaces, affecting the way they use them, their experiences and emotions; known in the literature as 'lived biocultural diversity' (Elands *et al.*, 2019). Similarly, individual apartments and single houses should have their own private outdoor space (e.g., balcony or terrace, domestic garden) allowing the possibility to grow herbs, food or flowers, etc., and easy access to fresh air, with particular attention for older people and people with reduced mobility (to avoid *social inequity consequences*) (Cameron *et al.*, 2012).

This discussion highlighted that designing green spaces to promote resilient built environments, and society in general, is not just a matter of planting some trees in particular locations or creating a residential park for children but of implementing a holistic approach that ensures (bio)diversity and interconnections and that is accessible and appealing, in which the needs of humans and non-human elements are met fully and achieved through democratic, participatory processes. Ultimately, this is about radically rewilding urban areas, and all of these aspects need to be extensively combined and connected together at the different scales (i.e., macro-, meso-, and micro-level) in a way that support wildlife, biodiversity and ecosystem functionality. In this respect, this paper does not propose a theoretical framework to design resilient green spaces (as those existing framework are already found in the literature review; see earlier and e.g., Zölch et al. 2017; Simonson et al. 2021; Raymond et al. 2017; Lee, Jordan, and Horsley 2015; Jerome et al. 2019; Dorst et al. 2019; Di Sacco et al. 2021; Calliari, Staccione, and Mysiak 2019; Bush and Doyon 2019; IUCN 2020). Instead, this paper defines a set of key conditions and considerations (see Table 1) that policymakers, planners, designers, practitioners and citizens can consider when thinking about the implementation of green spaces to promote a resilient built environment.

Table 1. Summary of key conditions and considerations to design green spaces as part of a resilient built environment.

Conditions	Key considerations	Unintended consequences
(Bio)diversity	✓ Diversity of green infrastructure (flora and fauna) at different scale ✓ Diversity of plants with seasonal interest (i.e., evergreen or deciduous) ✓ Use of indigenous species ✓ Low-maintenance wildlife habitats ✓ Services for a wide range of users and communities ✓ Support of non-human elements, i.e., wildlife ✓ Vegetation that provides	✓ Indigenous plants extinction ✓ Malfunction of the whole ecosystem due to combining species form different habitats ✓ Disturbance of non-human elements by human interaction ✓ No long-lasting

	shaded spaces outside ✓ Vegetation that provides shading for buildings, windows and balconies, courtyards, etc ✓ Trees grouped in squares or courtyards ✓ Consideration of local context to maximise the benefit from urban trees ✓ Protection of existing habitats (e.g., wasteland) ✓ Prioritisation (protection) of existing vegetation and species (mature habitats in particular) connecting mature and younger specimens ✓ Implementation of different kinds of sustainable drainage systems that deal with water run-off and increase biodiversity	
(Inter)connection	✓ Avoid fragmentation of green spaces ✓ Avoid demolition of trees and natural landscapes ✓ Integration of green open spaces into the city connected to the surrounding green spaces to create green corridor ✓ Use of pedestrian, cycle routes and green bridges to support humans and non-humans ✓ Co-development of green spaces with actors at different levels ✓ Apartments with private outdoor space, e.g., balcony or terrace ✓ Each apartment block has shared external green space ✓ Building spaces with views to urban nature, i.e., windows and balconies should provide views to nature ✓ Single houses with domestic garden ✓ Windows and balconies that provide natural ventilation ✓ Use of indoor plants	✓ Fragmentation of the natural environments ✓ Gentrification ✓ Displacement of most vulnerable residents ✓ Negative physical reactions in vulnerable people
Accessible	✓ Green spaces are accessible to different users and at different times of the year ✓ Provision of different typologies of spaces for different social users (humans and non-humans) and uses ✓ Design of green spaces to encourage social interaction	✓ Unequal distribution of spaces ✓ Loss of local identity and/or feeling of belonging ✓ Different use than expected

	✓ Provision of safe physical connections to nearby urban nature, such as a courtyard or residential park ✓ Allocation of green spaces no more than a 15-minute walk from housing development ✓ Provision of easy and safe access (e.g., clear signage, safe crossings, several entrances, access ways ✓ Provision of safe green spaces for children and other group ✓ Roadside with trees and grass with at least 1.5 m between crown and building façade and with 5-8 m between trees	
Appealing	✓ Co-development of green spaces with all community's members to ensure that their needs are met full ✓ Open for all community members to us ✓ Spaces with good sunlight and protected from noise, wind, rain and solar radiation ✓ Green spaces with different functions (e.g., recreation, relaxation, meditation) and for different users (i.e., children, youth, and older adults) ✓ Equally shared spaces for growing and harvesting flowers and herbs among the community ✓ Diversity of urban furniture and spaces (e.g., benches, areas for pets, playground, picnic tables, pedestrian paths ✓ Low-maintenance time and cost	✓ Risk of conflicts within the community due to different ways of thinking / cultural background ✓ Lack of feeling of ownership ✓ High maintenance cost

Limitations and further research

A limitation of this study is the time frame defined for the literature review (2011–2021) which may have excluded prior research not captured in subsequent studies and new research published since, excluding new insights on the benefits of green spaces. Similarly, the inclusion and exclusion criteria used for the paper screening may not have included other solutions published in non-academic articles. Furthermore, while the proposed set of key conditions to design green spaces in Table 1 can support the implementation of green spaces promoting resilience in the built environment, further research is needed to test and adapt the proposed items in contexts that are very different to those included in the systematic literature review, specifically those with different climatic, cultural, and built environment characteristics (e.g., no studies were included in Africa, Australia, South America)

Conclusions

The implementation of green spaces has increased attention in both policy and research, urging the need for the development of frameworks to effectively implement green spaces and assess their benefits for society. This paper, through a systematic literature review, builds on previous research and synthesised existing knowledge about the diverse role that green spaces play as part of a resilient society and specifically investigated what the key conditions are for green spaces to promote resilience in the built environment and maximise its benefits, while avoiding unintended consequences.

From the reviewed literature, 17 solutions were identified and categorised into five main groups: (1) urban environment restoration, (2) urban green spaces, (3) domestic solutions, (4) green roof systems, and (5) vertical greening systems. Findings highlight the importance of a diversity of green spaces in type (e.g., ecological corridors, wastelands), scale (e.g., community gardens, green roofs and walls, domestic gardens), and location (e.g., buildings, residential parks, forests) and their potential to support social inclusivity, community resilience and wellbeing. However, the literature showed the need to consider five key areas where unintended consequences could occur for an effective implementation of green spaces in the built environment. These were: temporal (i.e., it requires long-term perspective), spatial (everything is interconnected in terms of time and place), functional (solutions may counteract between each other), social inequity (coexistence of human and non-human elements), and species exclusion (i.e., avoid exclusion/extinction of indigenous species).

Building on these findings, four key conditions for green spaces that promote resilience in the built environment to multiple crises impacts were developed and discussed, highlighting that green spaces need to be designed in such a way that they (1) support *biodiversity*, (2) are *interconnected* with the context, (3) *accessible* and (4) *appealing* for citizens to protect and appreciate them. A set of key conditions and considerations to design green spaces as part of a resilient built environment is proposed (see Table 1) to support their implementation in different contexts, while avoiding unintended consequences. However, the testing and implementation of the proposed conditions in different cultural and built environment contexts (e.g., those that are very different to those included in the systematic literature review) has been highlighted for further research.

Furthermore, democratic, participatory approaches where all community's members are part of the co-development process are essential, as well as collaboration between private and public actors to ensure that functions, ecological process, and wildlife habitat quality are protected by effective policies.

Finally, existing frameworks mainly focus on developing resilient green spaces, infrastructures, etc. and/or assessing its effectiveness instead of understanding how to implement them in order to promote resilience in the built environment and society in general. This paper instead contributes to this research gap by providing a set of key interconnected conditions for the design of green spaces as part of a resilient society when faced with multiple crises impacts (e.g., 'climate crisis', 'housing crisis', 'pandemic crisis', 'financial crisis', 'demographic crisis', or 'digital crisis'), thereby aiming to promote future design and (re)development practices in the field and practical implications for policymaking.

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References

Africa, J. *et al.* (2019) ‘Biophilic Design and Climate Change: Performance Parameters for Health’, *Frontiers in Built Environment*, 5. doi: 10.3389/fbuil.2019.00028.

Ahsan, M. M. (2020) ‘Strategic decisions on urban built environment to pandemics in Turkey: Lessons from COVID-19’, *Journal of Urban Management*, 9(3), pp. 281–285. doi: https://doi.org/10.1016/j.jum.2020.07.001.

Allen, W. L. (2012) ‘Environmental Reviews and Case Studies: Advancing Green Infrastructure at All Scales: From Landscape to Site’, *Environmental Practice*, 14(1), pp. 17–25. doi: 10.1017/S1466046611000469.

Aman, A. *et al.* (2022) ‘Green corridor: A critical perspective and development of research agenda’, *Frontiers in Environmental Science*, 10. doi: 10.3389/fenvs.2022.982473.

Andreucci, M. B. *et al.* (2021) ‘Exploring Challenges and Opportunities of Biophilic Urban Design: Evidence from Research and Experimentation’, *Sustainability* . doi: 10.3390/su13084323.

Aradottir, A. L. and Hagen, D. (2013) ‘Chapter Three - Ecological Restoration: Approaches and Impacts on Vegetation, Soils and Society’, in Sparks, D. L. B. T.-A. in A. (ed.). Academic Press, pp. 173–222. doi: https://doi.org/10.1016/B978-0-12-407686-0.00003-8.

Bhunia, G. S. *et al.* (2021) ‘Chapter 5 - Wasteland reclamation and geospatial solution: existing scenario and future strategy’, in Bhunia, G. S. et al. (eds) *Land Reclamation and Restoration Strategies for Sustainable Development*. Academic Press, pp. 87–113. doi: https://doi.org/10.1016/B978-0-12-823895-0.00006-3.

Bonthoux, S. *et al.* (2014) ‘How can wastelands promote biodiversity in cities? A review’, *Landscape and Urban Planning*, 132, pp. 79–88. doi: https://doi.org/10.1016/j.landurbplan.2014.08.010.

Bush, J. and Doyon, A. (2019) ‘Building urban resilience with nature-based solutions: How can urban planning contribute?’, *Cities*, 95, p. 102483. doi: https://doi.org/10.1016/j.cities.2019.102483.

Bustamante, M. M. C. *et al.* (2019) ‘Ecological restoration as a strategy for mitigating and adapting to climate change: lessons and challenges from Brazil’, *Mitigation and Adaptation Strategies for Global Change*, 24(7), pp. 1249–1270. doi: 10.1007/s11027-018-9837-5.

Calliari, E., Staccione, A. and Mysiak, J. (2019) ‘An assessment framework for climate-proof nature-based solutions’, *Science of The Total Environment*, 656, pp. 691–700. doi: https://doi.org/10.1016/j.scitotenv.2018.11.341.

Cameron, R. W. F. *et al.* (2012) ‘The domestic garden – Its contribution to urban green infrastructure’, *Urban Forestry & Urban Greening*, 11(2), pp. 129–137. doi: https://doi.org/10.1016/j.ufug.2012.01.002.

Cariolet, J.-M., Vuillet, M. and Diab, Y. (2019) ‘Mapping urban resilience to disasters – A review’, *Sustainable Cities and Society*, 51, p. 101746. doi: https://doi.org/10.1016/j.scs.2019.101746.

Carrus, G. *et al.* (2013) ‘Relations between naturalness and perceived restorativeness of different urban green spaces’, *PsyEcology*, 4(3), pp. 227–244.

doi: 10.1174/217119713807749869.

Carrus, G. *et al.* (2017) 'A Different Way to Stay in Touch with "Urban Nature": The Perceived Restorative Qualities of Botanical Gardens', *Frontiers in Psychology*, 8. doi: 10.3389/fpsyg.2017.00914.

Casal-Campos, A. *et al.* (2018) 'Reliable, Resilient and Sustainable Urban Drainage Systems: An Analysis of Robustness under Deep Uncertainty', *Environmental Science & Technology*, 52(16), pp. 9008–9021. doi: 10.1021/acs.est.8b01193.

Cascone, S. (2019) 'Green Roof Design: State of the Art on Technology and Materials', *Sustainability*. doi: 10.3390/su11113020.

Castaño-Rosa, R. *et al.* (2022) 'Resilience in the built environment: Key characteristics for solutions to multiple crises', *Sustainable Cities and Society*, 87, p. 104259. doi: https://doi.org/10.1016/j.scs.2022.104259.

Catherine O., R. *et al.* (2014) 'Biophilic Design Patterns: Emerging Nature-Based Parameters for Health and Well-Being in the Built Environment', *Archnet-IJAR: International Journal of Architectural Research*, 8(2), pp. 62–76.

Cerè, G., Rezgui, Y. and Zhao, W. (2017) 'Critical review of existing built environment resilience frameworks: Directions for future research', *International Journal of Disaster Risk Reduction*, 25, pp. 173–189. doi: https://doi.org/10.1016/j.ijdrr.2017.09.018.

Chausson, A. *et al.* (2020) 'Mapping the effectiveness of nature-based solutions for climate change adaptation', *Global Change Biology*, 26(11), pp. 6134–6155. doi: https://doi.org/10.1111/gcb.15310.

Checker, M. (2011) 'Wiped out by the "Greenwave": Environmental gentrification and the paradoxical politics of urban sustainability', *City and Society*, 23(2), pp. 210–229. doi: 10.1111/j.1548-744X.2011.01063.x.

Chelleri, L. *et al.* (2015) 'Resilience trade-offs: addressing multiple scales and temporal aspects of urban resilience', *Environment and Urbanization*, 27(1), pp. 181–198. doi: 10.1177/0956247814550780.

Chen, K. *et al.* (2022) 'Review of the impact of urban parks and green spaces on residence prices in the environmental health context', *Frontiers in Public Health*, 10. doi: 10.3389/fpubh.2022.993801.

Corona, P. *et al.* (2012) 'Extending large-scale forest inventories to assess urban forests', *Environmental Monitoring and Assessment*, 184(3), pp. 1409–1422. doi: 10.1007/s10661-011-2050-6.

Damm, A. *et al.* (2019) 'Corrigendum to "Impacts of +2 °C global warming on electricity demand in Europe" [Clim. Serv. 7 (2017) 12–30]', *Climate Services*, 16, p. 100140. doi: https://doi.org/10.1016/j.cliser.2019.100140.

Danford, R. S. *et al.* (2018) 'Active Greening or Rewilding the city: How does the intention behind small pockets of urban green affect use?', *Urban Forestry & Urban Greening*, 29, pp. 377–383. doi: https://doi.org/10.1016/j.ufug.2017.11.014.

Dinić-Branković, M. and Marković, M. (2021) 'Revitalizing small urban streams as an instrument of urban planning in creating resilient cities', *Facta universitatis - series: Architecture and Civil Engineering*, 19(2), pp. 193–205. doi:

https://doi.org/10.2298/FUACE211203015D.

Dorst, H. *et al.* (2019) 'Urban greening through nature-based solutions – Key characteristics of an emerging concept', *Sustainable Cities and Society*, 49, p. 101620. doi: https://doi.org/10.1016/j.scs.2019.101620.

Draus, P. *et al.* (2020) 'Wastelands, Greenways and Gentrification: Introducing a Comparative Framework with a Focus on Detroit, USA', *Sustainability*. doi: 10.3390/su12156189.

ECRR (no date) *what is river restoration?*, *The network for best practices of river restoration in Greater Europe - European Centre for River Restoration*. Available at: https://www.ecrr.org/River-Restoration/What-is-river-restoration.

Eisenberg, B. and Polcher, V. (2019) *Nature Based Solutions – Technical Handbook*. Stuttgart, Germany. Available at: https://unalab.eu/system/files/2020-02/unalab-technical-handbook-nature-based-solutions2020-02-17.pdf.

Elands, B. H. M. *et al.* (2019) 'Biocultural diversity: A novel concept to assess human-nature interrelations, nature conservation and stewardship in cities', *Urban Forestry & Urban Greening*, 40, pp. 29–34. doi: https://doi.org/10.1016/j.ufug.2018.04.006.

European Commission (2013) *The EU Strategy on Green Infrastructure. Technical information on Green Infrastructure (GI)*. SWD/2013/0155. Brussels. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52013SC0155.

European Commission (2019) 'The European Green Deal'. Brussels, EU. Available at: https://ec.europa.eu/info/sites/info/files/european-green-deal-communication_en.pdf.

European Commission (2021) 'Biodiversity strategy for 2030'. Brussels: European Commission. Available at: https://environment.ec.europa.eu/strategy/biodiversity-strategy-2030_en.

Fairfax, E. and Whittle, A. (2020) 'Smokey the Beaver: beaver-dammed riparian corridors stay green during wildfire throughout the western United States', *Ecological Applications*, 30(8), p. e02225. doi: https://doi.org/10.1002/eap.2225.

Francoeur, X. W. *et al.* (2021) 'Complexifying the urban lawn improves heat mitigation and arthropod biodiversity', *Urban Forestry & Urban Greening*, 60, p. 127007. doi: https://doi.org/10.1016/j.ufug.2021.127007.

Frantzeskaki, N. *et al.* (2016) 'Elucidating the changing roles of civil society in urban sustainability transitions', *Current Opinion in Environmental Sustainability*, 22, pp. 41–50. doi: https://doi.org/10.1016/j.cosust.2017.04.008.

Frantzeskaki, N. (2019) 'Seven lessons for planning nature-based solutions in cities', *Environmental Science & Policy*, 93, pp. 101–111. doi: https://doi.org/10.1016/j.envsci.2018.12.033.

French, S. *et al.* (2013) 'Sense of Community and Its Association With the Neighborhood Built Environment', *Environment and Behavior*, 46(6), pp. 677–697. doi: 10.1177/0013916512469098.

Frumkin, H. *et al.* (2017) 'Nature contact and human health: A research agenda', *Environmental health perspectives*, 125(7), p. 075001. Available at: https://ehp.niehs.nih.gov/doi/pdf/10.1289/EHP1663.

Geels, F. W. (2004) ‘From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory’, *Research Policy*, 33(6), pp. 897–920. doi: https://doi.org/10.1016/j.respol.2004.01.015.

Gooden, J. and Pritzlaff, R. (2021) ‘Dryland Watershed Restoration With Rock Detention Structures: A Nature-based Solution to Mitigate Drought, Erosion, Flooding, and Atmospheric Carbon’, *Frontiers in Environmental Science*, 9. doi: 10.3389/fenvs.2021.679189.

Gorgoglione, A. and Torretta, V. (2018) ‘Sustainable Management and Successful Application of Constructed Wetlands: A Critical Review’, *Sustainability*. doi: 10.3390/su10113910.

Gough, D., Oliver, S. and Thomas, J. (2017) *An Introduction to Systematic Reviews*. 2nd editio. London: SAGE.

Grădinaru, S. R. and Hersperger, A. M. (2019) ‘Green infrastructure in strategic spatial plans: Evidence from European urban regions’, *Urban Forestry & Urban Greening*, 40, pp. 17–28. doi: https://doi.org/10.1016/j.ufug.2018.04.018.

Gunawardena, K. and Steemers, K. (2020) ‘Urban living walls: reporting on maintenance challenges from a review of European installations’, *Architectural Science Review*, 63(6), pp. 526–535. doi: 10.1080/00038628.2020.1738209.

Hartig, T. (2004) ‘Restorative Environments’, in Spielberger, C. D. B. T.-E. of A. P. (ed.) *Encyclopedia of Applied Psychology*. New York: Elsevier, pp. 273–279. doi: https://doi.org/10.1016/B0-12-657410-3/00821-7.

Hartig, T. *et al.* (2014) ‘Nature and Health’, *Annual Review of Public Health*, 35(1), pp. 207–228. doi: 10.1146/annurev-publhealth-032013-182443.

Hassler, U. and Kohler, N. (2014) ‘Resilience in the built environment’, *Building Research & Information*, 42(2), pp. 119–129. doi: 10.1080/09613218.2014.873593.

Im, J. (2019) ‘Green Streets to Serve Urban Sustainability: Benefits and Typology’, *Sustainability*. doi: 10.3390/su11226483.

IUCN (2020) *Global Standard for Nature-based Solutions. A user-friendly framework for the verification, design and scaling up of NbS*. Gland, Switzerland. doi: https://doi.org/10.2305/IUCN.CH.2020.08.en.

Jennings, V., Johnson Gaither, C. and Gragg, R. S. (2012) ‘Promoting Environmental Justice Through Urban Green Space Access: A Synopsis’, *Environmental Justice*, 5(1), pp. 1–7. doi: 10.1089/env.2011.0007.

Jerome, G. *et al.* (2019) ‘A framework for assessing the quality of green infrastructure in the built environment in the UK’, *Urban Forestry & Urban Greening*, 40, pp. 174–182. doi: https://doi.org/10.1016/j.ufug.2019.04.001.

Kabisch, N. *et al.* (2016) ‘Nature-based solutions to climate change mitigation and adaptation in urban areas: Perspectives on indicators, knowledge gaps, barriers, and opportunities for action’, *Ecology and Society*, 21(2). doi: 10.5751/ES-08373-210239.

Kristine, E. *et al.* (2019) ‘Residential green space in childhood is associated with lower risk of psychiatric disorders from adolescence into adulthood’, *Proceedings* *of the National Academy of Sciences*, 116(11), pp. 5188–5193. doi: 10.1073/pnas.1807504116.

Lang, S. and Rothenberg, J. (2016) ‘Neoliberal urbanism, public space, and the greening of the growth machine: New York City’s High Line park’, *Environment and Planning A: Economy and Space*, 49(8), pp. 1743–1761. doi: https://doi.org/10.1177/0308518X16677969.

Lee, A. C. K., Jordan, H. C. and Horsley, J. (2015) ‘Value of urban green spaces in promoting healthy living and wellbeing: prospects for planning.’, *Risk management and healthcare policy*, 8, pp. 131–137. doi: 10.2147/RMHP.S61654.

Lehmann, S. (2021) ‘Growing Biodiverse Urban Futures: Renaturalization and Rewilding as Strategies to Strengthen Urban Resilience’, *Sustainability*. doi: 10.3390/su13052932.

Loughran, K. (2018) ‘Urban parks and urban problems: An historical perspective on green space development as a cultural fix’, *Urban Studies*, 57(11), pp. 2321–2338. doi: 10.1177/0042098018763555.

Maffi, L. and Woodley, E. (2012) *Biocultural diversity conservation: a global sourcebook*. London: Routledge. doi: https://doi.org/10.4324/9781849774697.

Mansur, A. V *et al.* (2022) ‘Nature futures for the urban century: Integrating multiple values into urban management’, *Environmental Science & Policy*, 131, pp. 46–56. doi: https://doi.org/10.1016/j.envsci.2022.01.013.

Medl, A., Stangl, R. and Florineth, F. (2017) ‘Vertical greening systems – A review on recent technologies and research advancement’, *Building and Environment*, 125, pp. 227–239. doi: https://doi.org/10.1016/j.buildenv.2017.08.054.

Mitra, R. *et al.* (2020) ‘Healthy movement behaviours in children and youth during the COVID-19 pandemic: Exploring the role of the neighbourhood environment’, *Health & Place*, 65, p. 102418. doi: https://doi.org/10.1016/j.healthplace.2020.102418.

Mitra, R. and Manaugh, K. (2020) ‘Chapter Five - A social-ecological conceptualization of children’s mobility’, in Waygood, E. O. D. et al. (eds). Elsevier, pp. 81–100. doi: https://doi.org/10.1016/B978-0-12-814694-1.00005-1.

Mohajerani, A., Bakaric, J. and Jeffrey-Bailey, T. (2017) ‘The urban heat island effect, its causes, and mitigation, with reference to the thermal properties of asphalt concrete’, *Journal of Environmental Management*, 197, pp. 522–538. doi: https://doi.org/10.1016/j.jenvman.2017.03.095.

Moshfika, M., Biswas, S. and Mondal, M. S. (2022) ‘Assessing Groundwater Level Declination in Dhaka City and Identifying Adaptation Options for Sustainable Water Supply’, *Sustainability* . doi: 10.3390/su14031518.

National Geographic Society (2022) ‘Biodiversity’, *National Geographic*. National Geographic Society. Available at: https://education.nationalgeographic.org/resource/biodiversity.

Nature (2017) ‘“Nature-based solutions” is the latest green jargon that means more than you might think’, *Nature*, 541(7636), pp. 133–134. doi: 10.1038/541133b.

Newell, J. P. *et al.* (2013) ‘Green Alley Programs: Planning for a sustainable urban infrastructure?', *Cities*, 31, pp. 144–155. doi: https://doi.org/10.1016/j.cities.2012.07.004.

O'Neil, J. A. and Gallagher, C. E. (2014) 'Determining What is Important in Terms of the Quality of an Urban Green Network: A Study of Urban Planning in England and Scotland', *Planning Practice & Research*, 29(2), pp. 202–216. doi: 10.1080/02697459.2014.896154.

Pala, G. K. *et al.* (2021) 'Rainwater harvesting - A review on conservation, creation & cost-effectiveness', *Materials Today: Proceedings*, 45, pp. 6567–6571. doi: https://doi.org/10.1016/j.matpr.2020.11.593.

Parris, K. M. *et al.* (2018) 'The seven lamps of planning for biodiversity in the city', *Cities*, 83, pp. 44–53. doi: https://doi.org/10.1016/j.cities.2018.06.007.

Plaschke, M. *et al.* (2021) 'Green bridges in a re-colonizing landscape: Wolves (Canis lupus) in Brandenburg, Germany', *Conservation Science and Practice*, 3(3), p. e364. doi: https://doi.org/10.1111/csp2.364.

Rahman, M. A. *et al.* (2013) 'Hydrogeological analysis of the upper Dupi Tila Aquifer, towards the implementation of a managed aquifer-recharge project in Dhaka City, Bangladesh', *Hydrogeology Journal*, 21(5), pp. 1071–1089. doi: 10.1007/s10040-013-0978-z.

Raymond, C. M. *et al.* (2017) 'A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas', *Environmental Science & Policy*, 77, pp. 15–24. doi: https://doi.org/10.1016/j.envsci.2017.07.008.

Van Renterghem, T. (2019) 'Towards explaining the positive effect of vegetation on the perception of environmental noise', *Urban Forestry & Urban Greening*, 40, pp. 133–144. doi: https://doi.org/10.1016/j.ufug.2018.03.007.

Van Renterghem, T. and Botteldooren, D. (2016) 'View on outdoor vegetation reduces noise annoyance for dwellers near busy roads', *Landscape and Urban Planning*, 148, pp. 203–215. doi: https://doi.org/10.1016/j.landurbplan.2015.12.018.

Reynolds, H. L. *et al.* (2020) 'Implications of climate change for managing urban green infrastructure: an Indiana, US case study', *Climatic Change*, 163(4), pp. 1967–1984. doi: 10.1007/s10584-019-02617-0.

Romanelli, C. *et al.* (2015) *Connecting global priorities: biodiversity and human health: a state of knowledge review*. Switzerland. doi: 9789241508537.

Roslund, M. I. *et al.* (2021) 'Long-term biodiversity intervention shapes health-associated commensal microbiota among urban day-care children', *Environment International*, 157, p. 106811. doi: https://doi.org/10.1016/j.envint.2021.106811.

Di Sacco, A. *et al.* (2021) 'Ten golden rules for reforestation to optimize carbon sequestration, biodiversity recovery and livelihood benefits', *Global Change Biology*, 27(7), pp. 1328–1348. doi: https://doi.org/10.1111/gcb.15498.

Safikhani, T. *et al.* (2014) 'A review of energy characteristic of vertical greenery systems', *Renewable and Sustainable Energy Reviews*, 40, pp. 450–462. doi: https://doi.org/10.1016/j.rser.2014.07.166.

Sardeshpande, M., Rupprecht, C. and Russo, A. (2021) 'Edible urban commons for resilient neighbourhoods in light of the pandemic', *Cities*, 109, p. 103031. doi: https://doi.org/10.1016/j.cities.2020.103031.

Schiefer, D. and van der Noll, J. (2017) 'The Essentials of Social Cohesion: A Literature Review', *Social Indicators Research*, 132(2), pp. 579–603. doi: 10.1007/s11205-016-1314-5.

Schrecker, T. (2012) 'Multiple crises and global health: New and necessary frontiers of health politics', *Global Public Health*, 7(6), pp. 557–573. doi: 10.1080/17441692.2012.691524.

Schreier, M. (2012) *Qualitative Content Analysis in Practice*. 1st Editio. London, UK: SAGE Publications Ltd.

Sharifi, A. (2016) 'A critical review of selected tools for assessing community resilience', *Ecological Indicators*, 69, pp. 629–647. doi: https://doi.org/10.1016/j.ecolind.2016.05.023.

Shrubsole, C. *et al.* (2015) 'A tale of two cities: Comparison of impacts on CO2 emissions, the indoor environment and health of home energy efficiency strategies in London and Milton Keynes', *Atmospheric Environment*, 120. doi: 10.1016/j.atmosenv.2015.08.074.

Simonson, W. D. *et al.* (2021) 'Enhancing climate change resilience of ecological restoration — A framework for action', *Perspectives in Ecology and Conservation*, 19(3), pp. 300–310. doi: https://doi.org/10.1016/j.pecon.2021.05.002.

Sofo, Adriano and Sofo, Antonino (2020) 'Converting Home Spaces into Food Gardens at the Time of Covid-19 Quarantine: all the Benefits of Plants in this Difficult and Unprecedented Period', *Human Ecology*, 48(2), pp. 131–139. doi: 10.1007/s10745-020-00147-3.

Soininen, L. *et al.* (2022) 'Indoor green wall affects health-associated commensal skin microbiota and enhances immune regulation: a randomized trial among urban office workers', *Scientific reports*, 12(1), p. 6518. doi: 10.1038/s41598-022-10432-4.

Stewart, N. (2020) 'Chapter 7 - Urban green space, social equity and human wellbeing', in Verma, P. et al. (eds). Elsevier, pp. 111–127. doi: https://doi.org/10.1016/B978-0-12-820730-7.00007-0.

Tabb, P. J. (2020) *Biophilic Urbanism, Designing Resilient Communities for the Future*. 1st edn. Routledge.

Thörn, H. and Svenberg, S. (2016) '"We feel the responsibility that you shirk": movement institutionalization, the politics of responsibility and the case of the Swedish environmental movement', *Social Movement Studies*, 15(6), pp. 593–609. doi: 10.1080/14742837.2016.1213162.

Tidball, K. G. *et al.* (2018) 'Community-led reforestation: cultivating the potential of virtuous cycles to confer resilience in disaster disrupted social–ecological systems', *Sustainability Science*, 13(3), pp. 797–813. doi: 10.1007/s11625-017-0506-5.

Tuomi, J. and Sarajärvi, A. (2017) *Laadullinen tutkimus ja sisällönanalyysi (Qualitative research and content analysis) [e-book]*. 9789520400th edn. Helsinki: Tammi.

Turkelboom, F. *et al.* (2018) 'When we cannot have it all: Ecosystem services trade-offs in the context of spatial planning', *Ecosystem Services*, 29, pp. 566–578. doi: https://doi.org/10.1016/j.ecoser.2017.10.011.

Veról, A. P. *et al.* (2019) 'The urban river restoration index (URRIX) - A supportive tool to assess fluvial environment improvement in urban flood control projects', *Journal of Cleaner Production*, 239, p. 118058. doi: https://doi.org/10.1016/j.jclepro.2019.118058.

Vidal, D. G., Barros, N. and Maia, R. L. (2019) 'Public and Green Spaces in the Context of Sustainable Development BT - Sustainable Cities and Communities', in Leal Filho, W. et al. (eds). Cham: Springer International Publishing, pp. 1–9. doi: 10.1007/978-3-319-71061-7_79-1.

Vierikko, K. *et al.* (2016) 'Considering the ways biocultural diversity helps enforce the urban green infrastructure in times of urban transformation', *Current Opinion in Environmental Sustainability*, 22, pp. 7–12. doi: https://doi.org/10.1016/j.cosust.2017.02.006.

Vymazal, J. (2011) 'Constructed wetlands for wastewater treatment: Five decades of experience', *Environmental Science and Technology*, 45(1), pp. 61–69. doi: 10.1021/es101403q.

Wheeler, C. M. (2022) 'Multiple crises are changing the world', *RURAL 21. The International Journal for Rural Development*, 54(4), pp. 4–6. Available at: https://www.rural21.com/fileadmin/downloads/2022/en-03/rural2022_03-S04-06.pdf.

Wijesooriya, N. and Brambilla, A. (2021) 'Bridging biophilic design and environmentally sustainable design: A critical review', *Journal of Cleaner Production*, 283, p. 124591. doi: https://doi.org/10.1016/j.jclepro.2020.124591.

Wild, T. C. *et al.* (2011) 'Deculverting: reviewing the evidence on the "daylighting" and restoration of culverted rivers', *Water and Environment Journal*, 25(3), pp. 412–421. doi: https://doi.org/10.1111/j.1747-6593.2010.00236.x.

Wolch, J. R., Byrne, J. and Newell, J. P. (2014) 'Urban green space, public health, and environmental justice: The challenge of making cities "just green enough"', *Landscape and Urban Planning*, 125, pp. 234–244. doi: https://doi.org/10.1016/j.landurbplan.2014.01.017.

Xiao, Y. and Watson, M. (2017) 'Guidance on Conducting a Systematic Literature Review', *Journal of Planning Education and Research*, 39(1), pp. 93–112. doi: 10.1177/0739456X17723971.

Yang, W. *et al.* (2015) 'Comparative study of the thermal performance of the novel green (planting) roofs against other existing roofs', *Sustainable Cities and Society*, 16, pp. 1–12. doi: https://doi.org/10.1016/j.scs.2015.01.002.

Yang, Y. *et al.* (2021) 'Urban design attributes and resilience: COVID-19 evidence from New York City', *Buildings and Cities*, 2(1), pp. 618–636. doi: http://doi.org/10.5334/bc.130.

Yuan, J., Dunnett, N. and Stovin, V. (2017) 'The influence of vegetation on rain garden hydrological performance', *Urban Water Journal*, 14(10), pp. 1083–1089. doi: 10.1080/1573062X.2017.1363251.

Ziogou, I. *et al.* (2018) 'Implementation of green roof technology in residential buildings and neighborhoods of Cyprus', *Sustainable Cities and Society*, 40(March), pp. 233–243. doi: 10.1016/j.scs.2018.04.007.

Zölch, T. *et al.* (2017) 'Regulating urban surface runoff through nature-based solutions – An assessment at the micro-scale', *Environmental Research*, 157, pp. 135–144. doi: https://doi.org/10.1016/j.envres.2017.05.023.