Nature in the Urban Context: Renaturalisation as an Important Dimension of Urban Resilience and Planning

La naturaleza en el contexto urbano: La renaturalización como una dimensión importante de la resistencia y la planificación urbana

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Abstract

How are our cities confronting the challenges posed by a warming climate, the loss of biodiversity and major resource depletion? —This article discusses the opportunities and benefits of applying the concepts of renaturalisiation and rewilding of cities. It introduces Nature-Based Solutions (NBS) in urban planning that are integrated with the aim to enhance urban resilience and to slow down the biodiversity decline, which can be applied in two areas: through the conception of new green neighbourhoods; and through the regeneration and re-greening of existing but neglected parts of the city, such as postindustrial brownfields or economically weak districts. Contact to nature is essential for human existence, urban wellbeing and a good quality of life. Green spaces in cities –big or small– all contribute to health and wellbeing. However, many cities, including in the U.S. and in Europe, do not offer residents easy access to green space within the city. Improving better access to green spaces and extending gardens and parks will deliver a large number of benefits, such as ecosystem services, better water management for enhanced urban flood control, slowing down the biodiversity loss, contributing to food security, with the potential to restore damaged ecosystems. Furthermore, additional green space and NBS help to keep cities cool during heatwaves and improve the urban microclimate. As most of our cities keep growing and warming, the scale of the issue is significant. For example, in 2020, cities in the European Union were home to over 70 percent of Europe's population, and this figure is expected to increase to over 80 percent

by the middle of the century. This translates to 36 million new urban citizens in Europe by 2050 alone, who will need housing, employment, health care and access to green spaces (EU-Commission, 2018). In this context, nature-based solutions and re-greening can generate significant benefits for citizens, improve urban health and well-being, and offer an opportunity to effectively deploy nature in helping to resolve major societal challenges —such as social inclusion, food security and disaster risk reduction. However, as the discussion of this article shows, it is essential that the design of NBS is fully integrated with other complementary planning interventions and seeks synergies across all sectors.

Keywords: Renaturalisation; Nature-based Solutions; Strategic Planning for Urban Resilience; Re-greening Design Framework; Biophilic Urbanism; Integration of NBS in Urban Planning

Resumen

¿Cómo afrontan nuestras ciudades los desafíos que plantea un clima más cálido, la pérdida de biodiversidad y el importante agotamiento de los recursos? —Este artículo analiza las oportunidades y beneficios de aplicar los conceptos de re naturalización y reconstrucción de ciudades. Introduce Soluciones Basadas en la Naturaleza (SbN) en la planificación urbana que se integran con el objetivo de mejorar la resiliencia urbana y frenar el declive de la biodiversidad, que se pueden aplicar en dos áreas: a través de la concepción de nuevos barrios verdes; ya través de la regeneración y reverdecimiento de partes de la ciudad existentes pero abandonadas, como zonas industriales abandonadas postindustriales o distritos económicamente débiles. El contacto con la naturaleza es fundamental para la existencia humana, el bienestar urbano y una buena calidad de vida. Los espacios verdes en las ciudades, grandes o pequeñas, contribuyen a la salud y el bienestar. Sin embargo, muchas ciudades, incluidas las de EE. UU. Y Europa, no ofrecen a los residentes un fácil acceso a los espacios verdes dentro de la ciudad. Mejorar el acceso a los espacios verdes y ampliar los jardines y parques generará una gran cantidad de beneficios, como los servicios de los ecosistemas, una mejor gestión del agua para un mejor control de las inundaciones urbanas, ralentizar la pérdida de biodiversidad, contribuir a la seguridad alimentaria, con el potencial de restaurar los daños ecosistemas. Además, los espacios verdes adicionales y las NBS ayudan a mantener frescas las ciudades durante las olas de calor y mejoran el microclima urbano. Como la mayoría de nuestras ciudades siguen creciendo y calentándose, la magnitud del problema es significativa. Por ejemplo, en 2020, las ciudades de la Unión Europea albergaban a más del 70 por ciento de la población europea, y se espera que esta cifra aumente a más del 80 por ciento para mediados de siglo. Esto se traduce en 36 millones de nuevos ciudadanos urbanos en Europa solo para 2050, que necesitarán vivienda, empleo, atención médica y acceso a espacios verdes (EU-Commission, 2018). En este contexto, las soluciones basadas en la naturaleza y la re-ecologización pueden generar beneficios significativos para los ciudadanos, mejorar la salud y el bienestar urbanos y ofrecer una oportunidad para desplegar la naturaleza de manera efectiva para ayudar a resolver los principales desafíos sociales, como la inclusión social, la seguridad alimentaria. y reducción del riesgo de desastres. Sin embargo, como muestra la discusión de este artículo, es esencial que el diseño de las SbN esté completamente integrado con otras intervenciones de planificación complementarias y busque sinergias en todos los sectores.

Palabras Clave: Re naturalización; Soluciones basadas en la naturaleza; Planificación estratégica para la resiliencia urbana; Marco de diseño re-ecológico; Urbanismo biofílico; Integración de SbN en la planificación urbana

INTRODUCTION

Stopping the decline of the quality of life in cities

Over the centuries, humanity has become a force that changes the planet. Now this change has become so fundamental that it could finally overturn the Earth system. Our current disconnect from Nature has evolved over the last 300 years with the emergence of science, technical progress and the subsequent Industrial Revolution. "Within a very short time, humans have experienced a transition from a life predominantly spent outside, towards a very different life mostly inside buildings and in an urban context—and, a fundamental change in our relationship with nature has been the result. Over 80 percent of the U.S. population currently live in urban areas and a large portion "are estranged from nature" (Office for National Statistics-ONS, 2016, p. 2). Today, 90 percent of our lives is spent indoors, in controlled interior environments (American Society of Heating, Refrigerating and Air-Conditioning Engineers-ASHRAE, 2010); with an increasing time spent as "screen-time" online, alone.

Cities are also centers of consumption: 75 percent of our natural resources are consumed in and by cities; and cities are responsible for 50 percent of the world's waste, and emit 60 to 80 percent of global greenhouse gas emissions. Moreover, by 2050, metropolises have to solve the challenge of accommodating more residents, offering a higher quality of life and buffering the consequences of climate change. This is a big call. At the same time, urban ecosystems are under stress, as they have to withstand more frequent and longer dry periods with increasing heat, air pollution and water shortages (Intergovernmental Panel on Climate Change-IPCC, 2018).

Over the recent years, the quality of life in many cities has declined. Reasons for this decline include the air-pollution, ever-increasing traffic —mostly private cars— and housing that has become unaffordable. Therefore, we must plan better ahead —including for the further increase of urban population— that we will not lose the livability of our cities we currently enjoy.

We face an array of societal challenges, which in the past we have tried to solve in a way that was not always successful. It has led to urban sprawl, worldwide biodiversity loss and a climate crisis, increased inequalities and global human vulnerability. Moreover, evidence shows that an urbanisation model resulting in urban sprawl is wasteful in terms of land use, energy use, and other resources—wasting time, which we could better spend with family instead of being stuck in traffic. Urban sprawl is a phenomenon that plagues cities in both developing and industrial countries. A study by UN-Habitat (United Nations Human Settlements Programme) shows that since 2000, urban densities are worldwide in decline, a result of rampant land consumption (in the U.S., for example, land development has quadrupled since 1945, growing twice the rate of population growth). In addition, evidence from

research shows that sprawl has a negative social impact, leading to more isolation, loneliness, and cases of depression and obesity (Grinde & Patil, 2009; Woo, Wortmann, Schurig & Leidreiter, 2014; Hand et al., 2017; Lehmann, 2017; UN-Habitat, 2020).

Every city is unique. Cities not only differ in their size, density and the distribution of their population and green spaces, but also in their climatic and cultural context, geography, and in the ways in which they are vulnerable to climate change. When it comes to enhancing urban resilience through applying Nature-Based Solutions (NBS) and re-greening strategies, what works in one city may not work in another. However, urban re-greening projects generally allow for "repairing" and restoring some of the damage caused to ecosystems whilst enhancing their urban resilience.

Good urban design and planning can make a profound positive contribution about solving the challenges of climate change as well as societal challenges. Transforming the practice of planning and architecture must lead to the delivery of coherent and robust urban design, and not just architectural objects. Combined with strategies for gentle densification, different urban infill scenarios, and the integration of nature-based solutions —the urban transformation and regeneration will need to be dense and green, both at the same time. As numerous projects have shown, this is not a contradiction; we can have both: dense and green combined.

Working definitions

The following part provides short working definitions of the terms: Nature-Based Solutions (NBS), urban resilience, the Urban Heat Island (UHI) effect, urban greening, and biophilia.

The term nature-based solutions refer to the use of nature for tackling environmental, cultural and societal challenges while increasing biodiversity and balancing urban temperatures of the city cores[1].

According to International Union for Conservation of Nature-IUCN (2020), nature-based solutions are "actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits".

Urban resilience of cities means their ability to maintain human and ecosystem functions simultaneously over the long-term, even during a disaster or crisis; and their capacity to deal with sudden change and continue to develop (Alberti & Marzluff, 2004). Urban resilience, also called *adaptive capacity*, refers to a city's ability to cope with and recover quickly from hardship or crisis. A resilient city is typically one that is prepared and well equipped to contend with and mitigate the multiple effects

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[1] A comprehensive list of NBS measures inspired and supported by nature (compiled by the EU-Commission, 2020, with a link to the NBS Atlas).

of climate change, such as heatwaves, urban flooding, energy blackouts, and other potential disasters. A resilient city has a robust infrastructural system and can turn a crisis into a positive development (Mitchell & Harris, 2012; Meerow, Newell & Stults, 2016; Lehmann, 2018).

The dangerous underline urban heat island effect leads to significantly warmer urban areas compared to surrounding suburban or rural areas, and this temperature difference is usually larger at night than during the day. The UHI effect occurs because the dense, dark surfaces (e.g., black asphalt on roads, or concrete on building roofs) absorb and store heat during the day and then release it at night. Urban greenery can help reduce this heat gain and the negative impact on human health (Sailor, 2014; Lehmann, 2015).The main cause of the UHI effect is from the modification of land surfaces and material, for instance concrete roofs that store and trap solar radiation heat during the day. Therefore, green roofs and facades can best counteract it with planting and vegetation, white or light-colored surfaces (using the *Albedo Effect* to reflect solar radiation), and the use of materials that absorb and store less heat.

Understanding the many benefits of underline urban greening, municipalities are now looking at how urban areas can adapt their landscapes to better manage the increasing heat stress —the UHI effect— and to build adaptive capac-ity. Urban greening refers to the process of establishing the components of green infrastructure and plants within the built environment. There is growing appreciation that re-greening cities helps to provide viable solutions using and exploiting the properties of natural ecosystems and the services that they provide. Ecosystem services that city vegetation delivers, through healthy street trees, tree-lined avenues, gardens, parks, wetlands, urban forests, green roofs and living walls, are now becoming more appreciated and part of urban master planning.

The concept of *Biophilia,* introduced by Stephen Kellert & Edward O. Wilson (1984), suggests that humans possess an innate tendency to seek connections with nature and other forms of life (Kellert, 2011). As already predicted by Rachel Carson in *Silent Spring* in 1962, we are now in the process of redefining our relationship with nature and how our health depends upon it (Carson, 1962). This growing understanding is not about giving up technology, but rather about developing the most advanced technologies and nature-based solutions to date; for instance, through the biological revolution, digital engineering and nanotechnology. We have to use that rich and available knowledge to find innovative and better solutions for cities, employing ideas of *Biomimicry*–innovation inspired by natural systems (Benyus, 2002; Neves & Francke, 2012).

From Howard's garden cities, to McHarg's environmental manifesto, to biophilic urbanism: a way to healthy and resilient cities

As far back as in the 1722 book "The City Gardener", the English botanist Thomas Fairchild (1667-1729) noted that "city residents feel more relaxed and healthy when they can enjoy gardens and greenery" (Fairchild, 1722). From Descartes (1637), to Fairchild (1722), Howard (1902), McHarg (1969), and Meadows, Meadows, Randers & Behrens (1974), there are direct linkages that exist between a rich palette of seminal literature and different schools of thought about the possible role of nature-based solutions within the city. The great cities of the past were traditionally penetrated by fields, orchards, gardens, meadows and fishponds right alongside their largest and most significant building, the church or cathedral. Ebenezer Howard's vision of the garden city movement (published in 1902) proved to be enormously influential in city planning circles throughout the world (Howard, 1902). From garden cities to biophilia, reconnecting cities with nature means enhancing resilience at the urban scale; and there is growing recognition of the need for daily contact with nature and green spaces in order to live happy, productive and meaningful lives.

The seminal publication *Design with Nature* (McHarg, 1969) was the first environmental manifesto to explore green spaces in cities, and how the ethos of designing with nature has evolved over the 20th century. With the threat of climate change, species extinction and major resource depletion, McHarg addressed the need for broader co-ordination, longer-term strategies and clarity of policy, leadership and action (Steiner, Weller, McCloskey & Fleming, 2019).

The Limits to Growth (Meadows et al., 1972) was immensely important in the way it challenged the common thinking of the time about land consumption, finite resources and the concept of endless growth; shortly after, it was followed by James Lovelock's pivotal book *Gaia, a new look at life on Earth* (Lovelock, 1979).

Today, cities can possess degrading conditions—just think of windowless work environments, over-crowded housing, air pollution, noise, and the lack of any street trees (Lehmann, 2020; 2019a). Cities are not obvious places to reconnect with the natural environment. Cronon (1995) asserts that urban inhabitants have created a wholly artificial view of what nature and wilderness are, based on ideas of open space and grandeur that rarely correspond to the lived reality of the people who inhabit suburban or rural spaces. The view of nature as a pristine and uninhabited space makes it difficult to see nature on a smaller, less imposing scale, and to appreciate for instance that a tree in an urban back garden can equate to a tree growing in a forest; that the two trees are identical despite the different setting. In our mind, the forest tree somehow has a greater perceived natural value, and nature is seen as being something that does not necessarily belong within the city (Cronon, 1995).

Biophilic urbanism uses the calming and cooling effect of nature as a tool in urban planning.

It is about new ways to combine density with greenery to enhance urban resilience. The strategy is to have more urban greenery and higher densities, at the same time (as was recently realised successfully in Singapore, Milan and Barcelona). Dense and green is not a contradiction: it is about increasing urban density, while at the same time increasing the amount of accessible green space, and integrating urban greenery in new ways, including urban food production and farming on roofs of large buildings. Thus, increasing urban density must mean more green spaces and the integration of vegetation into the urban fabric.

Urban planners' worldwide aim to bring nature back into the city, to compensate for the lack of parks, gardens and green spaces. The concept of *Urban Metabolism* understands cities as a vulnerable living organism. Urban metabolism analyses the flows of energy, resources, food, people and waste/materials in cities (as if the city were a living ecosystem) and provides a framework for the study of the interactions of natural and human systems, using the metaphor of the city as a living organism. Ecologist Arthur George Tansley (1871-1955) expanded the term to encompass the material and energetic streams (Tansley, 1935). Seminal texts by different authors offer further ecological wisdom on the planner's relationship with nature, landscapes and their ecosystems (Carson, 1962; McHarg, 1969; Register, 1987; McDonough & Braungart, 2002; Girardet, 2008; Lehmann, 2010).

Today, in the United States, over 50 percent of the population lives in suburbs of dispersed, car-dependent cities. In cities like Houston, Dallas, Phoenix or Las Vegas, this figure is even closer to 80 percent. San Diego in Southern California is a classic example of a sprawling metropolis with mile after mile of scattered low-density car-dependent development.

In the 1970s, Portland in Oregon has offered a pioneering solution with the creation of a strict urban growth boundary to protect the surrounding agricultural land from ever-increasing sprawl. At the same time, Portland saw a significant investment in public transport such as a light-railway system connecting the suburbs with downtown. Almost five decades ago, Oregon adopted strong urban planning requirements, including the urban growth boundary that has led to urban containment and a more compact city form. The growth boundary has ensured that the city grew inwards and became compact rather than further increasing its footprint. As a consequence, for the last thirty years, a renaissance of the urban core has been underway that is making a dense urban lifestyle more practical; it made Portland one of the most walkable and liveable cities in the entire U.S., and the trade-off of preserving as much natural habitat around the city as possible resulted in greater regional biodiversity (Figure 1).

Urban sprawl means excessive land consumption. In Germany alone, over one hundred square kilometers of greenfield land is sealed every year, built on or paved over. Consequently,

the rainwater can no longer seep away to join the groundwater, often leading to urban flooding after heavy rainfall. The days of heavy rainfall are 85 percent more common in Europe today than a hundred years ago, and scientists predict that this trend will continue until 2100.

Planners and architects have long advocated for increased density and walkable, compact, mixed-use, transit-oriented development, combined with greening strategies, in order to improve city residents' life, combat sprawl and mitigate climate change. The strategies are: 1) Stopping to build on greenfield sites and into the surrounding landscape by establishing a strict urban growth boundary. 2) The re-naturing of the city means that the landscape is allowed back into the city, and not the other way around–the city eating into precious landscape. Instead, the landscape fingers extend into the city. 3) Applying NBS, including planting urban forests, has shown to be very beneficial (e.g., in Melbourne, Australia, Figure 2), as it keeps cities cooler during heatwaves and sequesters CO_2 emissions. 4) Living walls have become a popular feature in architecture worldwide (Figure 3). Plants reduce the heat load and clean the air, which allows for more natural cross-ventilation and smaller air-conditioning plants. More and more green roofs are now designed with native plants and with productivity and water saving in mind.

Figure 1. The benefits of compact development: thanks to its strict urban growth boundary and anti-sprawl approach in planning, the city of Portland (Oregon, USA), has emerged as one of the most walkable and liveable cities in the entire United States.

Figure 2. An urban forest in Melbourne, Australia, helps to keep the city cooler during heatwaves and binds dust from traffic. The City of Melbourne has formally embraced an Urban Forest Strategy with the aim to increase tree canopy cover from 22 percent to 40 percent by 2040 (the Strategy 2012-2032 is available online: https://www.melbourne.vic.gov.au/community/greening-the-city/urban-forest/Pages/urban-forest-strategy.aspx)

Source: City of Melbourne (2011).

Figure 3. Vertical garden (living wall) in Madrid. Living walls have become popular over the last ten years; however, some have problems with irrigation or selection of plant species and have become a maintenance burden.

Source: Zarateman, 2015 [wikimedia, CC0 1.0]. https://commons.wikimedia.org/wiki/File:Madrid_-_CaixaForum,_jard%C3%ADn_vertical_1.jpg

The recent IPCC Report and numerous other research confirm that more plants, trees, vegetation and greenery in the city will reduce the heat load, the UHI effect, as large-leaf trees bind the dust, clean the air, and reduce the size required for the air-condition plant (Pauleit, Jones, Nyhuus, Pirnat & Salbitano, 2005; Bowler, Buyung-Ali, Knight, Knight & Pullin, 2010; Doick, Peace & Hutchings, 2014; Schwarz et al., 2015; IPCC, 2018; Sharifi, Lehmann & Zawarus, 2021). As consequence, many cities have started to question the outdated 20th-century concept of infinite urban growth, and are now searching for new ways to enable more sustainable, compact inner city living on a reduced area of land per capita that does not trigger gentrification.

Understandingly, there is now a revival of the 19th-century compact European city model (a model that can be found in Berlin, Paris, Milan, Barcelona, Athens, Stockholm and numerous other compact cities), as it is the most energy-efficient and resourceful of all urban models. It creates a reasonable population density (at around 80+ residential units per acre), and does not waste valuable land. It does not generate unnecessary traffic or waste energy, but offers:

- Quiet green courtyards, which allow for natural cross-ventilation.
- A diversity of public spaces, squares and streets as places for re-greening,
- 5- and 6-storey mixed-use urban blocks that share walls and circulation.

The compact walkable European city model is the most sustainable way of urbanisation as it means the lowest use of land and resources.

PRINCIPLES FOR THE INTEGRATION OF NBS INTO URBAN PLANNING

The positive impacts on land, water, air, urban heat, biodiversity, health and well-being

Scientists are now closely examining all relevant issues for the design of nature-based solutions, such as impacts on land, water and air, urban heat, biodiversity, recreation, and health and well-being. Evidence shows that there can be considerable positive impacts generated by NBS in the transformation and revitalization of cities. NBS are tackling environmental and societal challenges while increasing biodiversity. In addition, NBS help to keep cities cool, reduce the heat load, bind dust, manage storm water run-off and support the healthy city agenda; as well as deliver positive impact from ecosystem services provided by nature within the city. Researchers are working to identify the most impactful principles for the integration of NBS at the urban planning level, looking at new forms of urban greenery in regeneration projects, and the protection and expansion of existing green spaces as an important component in re-greening cities.

A definition of NBS offered by the European Union Commission, which has been funding critical research in NBS over the last ten years, states: These solutions are "inspired and supported by nature, which are cost-effective, simultaneously pro-

vide environmental, social and economic benefits and help build resilience (…) and bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions" (Rizvi, Baig & Verdone, 2015; Shanahan et al., 2015; EU-Commission, 2015; EU-Commission, 2017; Fields in Trust, 2018).

Thus, NBS provide practical, sustainable, cost-effective and adaptive alternatives for various urban planning objectives; by working with nature, rather than against it, it becomes possible to take further steps towards a more competitive, resource efficient and greener economy (often termed "green growth"). It can also help to enhance natural capital rather than depleting it. For instance, green roofs or living walls can be used to reduce the impact of high temperatures, collect storm water, reduce pollution and fine dust, and act as carbon sinks, all whilst simultaneously enhancing biodiversity. Similarly, the collection and storage of rainwater in constructed wetlands, or the protection of mangrove forests along coastlines utilise nature-based solutions to achieve several objectives, including disaster risk reduction and halting species extinction. Urban flood control is regulated in a natural way, with mangroves alleviating the impact of wind and waves on coastal settlements or cities whilst also capturing CO_2. Additionally, the mangrove forests can provide safe nurseries for marine life and help control coastal erosion resulting from a rise in sea-levels, mitigating potentially harmful

effects on the environment and on human health and society (Lennon & Scott, 2014; Kabisch et al., 2016; Maes & Jacobs, 2017; Rich, 2018; World Forum on Natural Capital, 2018).

Such new urban design concepts incorporate and re-introduce greenery and biodiversity into the urban built environment, subsequently leading to new models of urbanisation. It is essential that the design of NBS is integrated with other complementary planning interventions and seeks synergies across all sectors. Maintaining biodiversity in the face of urbanisation, and slowing down habitat loss, habitat fragmentation, and environmental deterioration are some of the extreme challenges of the present day. The inclusion of trees, shrubs and other plant matter into urban green spaces, gardens and onto roofs is of paramount importance in helping to keep the urban landscape cool, mitigating against buildings and pavements which increase heat absorption and heat storage, leading to the UHI effect (Hawken, Lovins & Lovins, 1999; Watts, 2018).

The regeneration of abandoned or neglected urban areas can be achieved through the restoration of damaged ecosystems: urban regeneration projects allow us to repair and restore some of the damage while enhancing walkability and urban resilience. For instance, increasing connectivity between existing and enhanced ecosystems and restoring them within cities and at the peri-urban fringe through nature-based solutions and the re-naturing of neighbourhoods is necessary to strengthen resilience and the adaptive capacity of cities to better cope with the effects of climate

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change. Nevertheless, it is not as simple as the more trees one has in an urban space, the better the air quality will be. Some trees are markedly more effective at filtering pollutants from the air than others. For effective renaturing of our cities, it is important to explore which tree species is doing the best job; for example, conifers offer the best Particulate Matter (PM) reduction because they are an evergreen species. It also depends on canopy size, leaf size and leaf structure.

Regenerating and bringing nature back into the city: the case for tree planting and rewilding of urban spaces

With more and more people living in urban areas, the need to create and enhance green spaces around and within cities has never been greater. Some large cities, like Brussels or Bangkok, have far too little green space within their urban areas. Bangkok, for example, has one of the lowest levels of public green spaces per capita of cities in Asia. It is no coincidence that the Thai capital city frequently struggles with urban flooding: after heavy rain, stormwater cannot drain, and there are no green spaces to slow down, store and reduce the water runoff. Centenary Park is now the first new public park project in Bangkok in 30 years and it will add 11-acre green space.

Figure 4. A map of London showing the green spaces. Every green space in the city, big or small, contributes to health and wellbeing.

Source: London Green Cover, 2020 [maps]. https://maps.london.gov.uk/green-cover/

Ambitious greening projects are also on the way in several megacities, including New York City, which planted a million trees between 2007 and 2015; and London: the British capital hopes to green more than half the city by 2050 to make the world's first "National Park City", while Paris recently announced that it is creating four inner-city urban forests in 2020 (Figure 4).

As climate change brings hotter temperatures and unpredictable downpours, cities are expecting a new kind of resilience from their urban green spaces and trees. There are numerous tree-planting programs on the way. In the European Union (EU), three billion new trees will be planted across the 27 member states by 2030, many in and around cities. Some European politicians have become influential advocates for prioritising nature restoration as part of the "EU Biodiversity Strategy for 2030: Bringing Back Nature" (EU-Commission, 2019).

However, while planting trees in urban spaces is an effective and efficient way to adapt to climate change, it is not a holistic solution. Furthermore, trees are not always seen as a benefit and street trees in the city are in a constant struggle for water and space. If we want to reap the benefits of urban treescapes, ecologists say it is vital that trees are seen as more than just an aesthetic addition to cities. Trees are also regulating urban microclimates —filtering air pollution, absorbing CO_2, providing shade, helping prevent flash flooding, as well as reducing the urban heat island effect. The cooling effect of trees to shade buildings is significant; it can cool them down by up to five degrees Celsius.

Trees' cooling effect is an important tool councils can wield against both heat stress and cooling costs. Alongside the ecosystem-services that urban trees provide, there are also qualities that we cannot put a direct monetary value on, including biodiversity, aesthetics and our psychological need to experience nature. People who live in places with more trees and parks experience lower levels of stress and mental illness, confirming the concept of biophilia—the idea that humans have an innate desire to connect with nature. Establishing or reinforcing people's connection with wild nature is increasingly recognised as critical to their mental and physical health, a fact that has been reinforced by the recent COVID-19 pandemic.

One solution to preserving city trees that has grown in popularity is citizen involvement in urban tree caretaking. New York City's citizen pruner program allows city dwellers to take classes to become official city tree carers; and Berlin is now allowing residents to maintain tree pits and has proposed that citizens should water street trees in summer.

Beyond using trees as geo-engineering fix, urban ecologists point out that more trees in cities could also change our perspectives on urban living and give people a greater understanding of how to value nature in general as part of a sustainable, livable city–not separate from it.

Nevertheless, it needs the right tree selection for each place; planting monoculture plantations on abandoned land typically creates forests that are of low biodiversity value and with little CO_2 carbon storage capacity. Instead, we should focus on restoring the natural woodland ecosystems in all their biodiversity.

Restoring urban areas and regenerating ecosystems by using natural systems has been recognised as an effective solution for many years. Adding green roofs and plants to the tops and sides of buildings provides significant ways to improve the urban microclimate; and wet roofs that temporarily store water can help to cool buildings naturally through evaporative cooling. There are now plans for urban landscape restoration and rewilding projects worldwide with the aim to create leafy, resilient and healthy places in cities. Berlin's former inner-city airport Tempelhof has been turned into a natural oasis and popular public recreation area: Tempelhof Field has been successfully renatured, offering also a very efficient carbon sink. Another successful project is Big Marsh Park, a former steel mill and dumping ground on Chicago's Southeast Side that has now hiking trails and an environmental education center to help the population reconnect with nature (Figure 5).

Figure 5. The Tempelhofer Feld (Tempelhof Field) is a new public recreational area on the former inner-city airport in Berlin. The airport closed in 2008 and its enormous 386-hectare open space, the former airfield, was turned into a public park (opening in 2010), offering cycling, skating and jogging trails, urban gardening sections and a large rewilding area.

"Rewilding" means to let green spaces develop without the interference of humans. It means to let nature take its course over a number of years, so wildlife can flourish —an effective NBS strategy that is not technology-dependent and tackles the climate crisis with a minimal amount of resources. A return to the wild for selected under-used urban areas can be a powerful way to re-introduce lost biodiversity back into our cities and bring communities into closer connection with nature. In Australia, a successful project turns a disused golf course back into a swamp and wetland, which has become a hotspot for local native species and formerly locally extinct flora and fauna. Rewilding gardens can create "green lungs" and even improve local economies through nature-based tourism. It is timely to rethink the idea of merely planting trees, and instead support the landscape-scale development of natural forests in and around cities.

Municipalities are interested in the question: which trees do the best job in cutting air pollution and improving air quality? It is not as simple as the more trees in an urban space, the better the air will be. Some tree species are markedly more effective at filtering and removing pollutants from the air than others are. Some trees are like air purifiers: they filter atmospheric pollutants like Sulphur dioxide and Nitrogen dioxide through their leaves. Nano particles and fine dust (e.g., from diesel engines, factories, or construction sites) are inhaled and enter into the human respiratory system, causing a number of illnesses. The extent to which each tree species performs the filtering activity depends mostly on canopy size, leaf size and leaf structure. In general, bigger tree canopies trap more particles and larger leaves can trap more pollutants than small ones. UK researchers have tested the ability of different tree species and found that trees with rough, hairy leaf surface and large leafs act as the best filters; e.g., silver birch, silver maple, and conifers such as pine trees were very effective. They found that trees with a dense large canopy and evergreen species are the most effective pollutant-trappers, while yew hedges make good roadside additions to reduce pollution.

With new summer record temperatures, cities should be greened at record speed. In a green city future, all flat roofs of buildings will need to be used as roof gardens and water reservoir for plants. Scientists have found out that one square meter of green roof binds up to ten grams of fine dust per year, and absorbs 375 grams of CO_2. In addition, green roofs reduce surface temperature and heat losses from the buildings.

Urban greenery requires valuable drinking water, especially in the hot summer months, and native plants need generally less irrigation. So what kind of greenery should be prioritise? How can it be possible to bring more green into cities despite the lack of space and the high costs of infrastructure? In the city, every tree and every bush must compete for space. Forget the expensive decorative green of the maintenance-intensive parks, golf courses and manicured

lawns—green must become part of the basic city infrastructure, so urban greenery has a lobby and thus it has space and budget. The Chinese "Sponge City" concept stores water during heavy rainfall: parks become water reservoirs and biotopes in which a large number of animal and plant species can coexist.

Researchers at Wageningen University found out that a 150-year-old beech tree bears around 800,000 leaves, which it uses to evaporate up to 500 liters of water every day. During the same period, the tree absorbs up to 24 kilograms of CO_2 (as much as a small car blows into the air for 150 kilometers) and produces around 11.000 liters of oxygen—the daily breathing requirement of 26 people. In Mexico City, most of the local pollution is attributed to the excessive use of private cars. Mexico City has planted "green columns" alongside highways and underneath flyovers, and turned pillars into green walls that reduce the fine dust and pollutants for residents along the inner-city freeways. Since 2016, over 1.000 concrete columns have been turned into vertical walls (Figure 6).

Figure 6. Mexico City has planted "green pilotis" underneath their freeways to create a kind of green wall that reduces the fine dust and pollutants for residents along the inner-city freeways. These vertical gardens on columns along the Periférico highway, which rings the central city, were the only possibility since there is no space to plant trees.

Source: Via Verde, 2017 [twitter].
https://twitter.com/viaverde_cdmx/
status/943310573487390720/photo/1

180
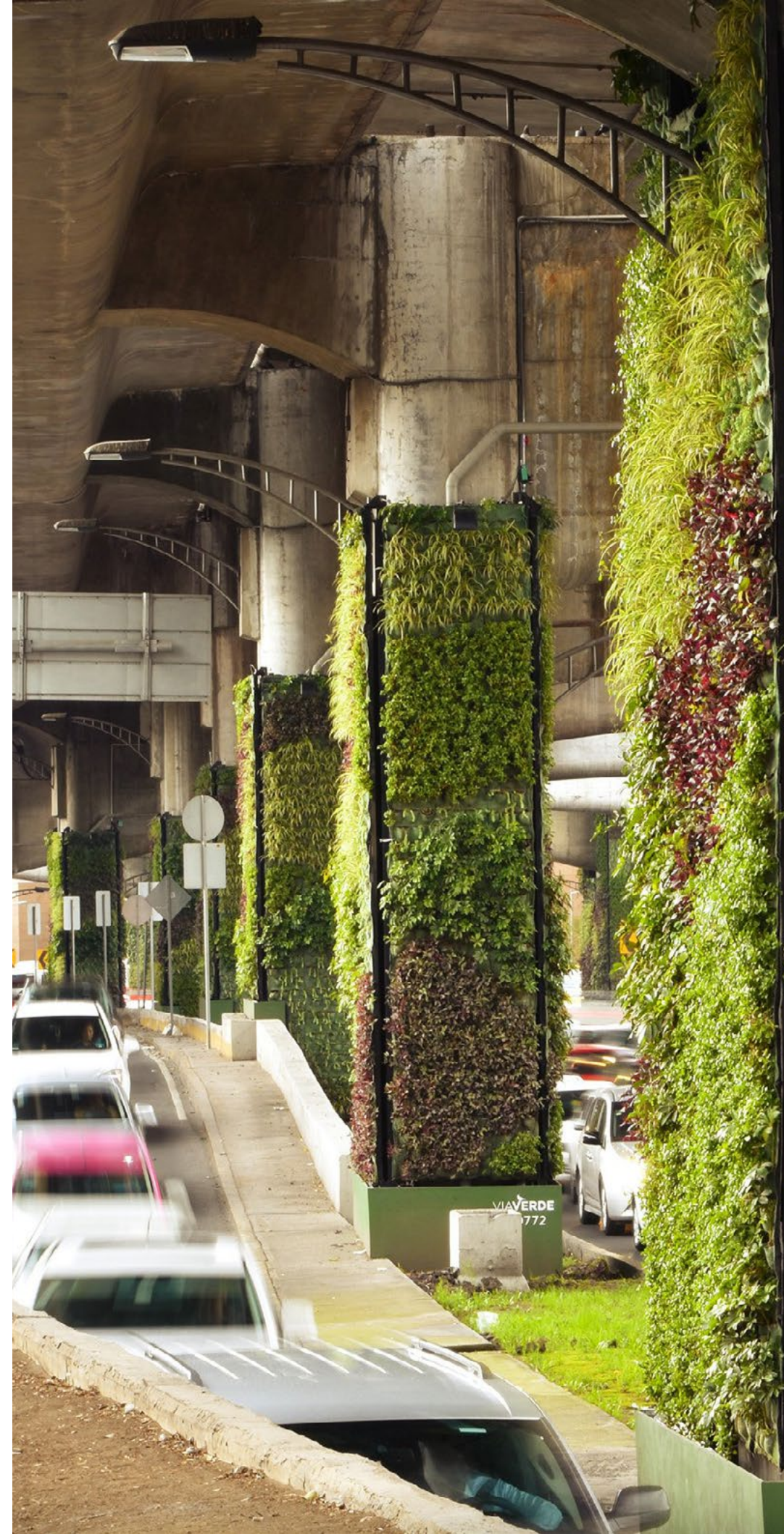
In the American Southwest region, large parking lots are common that store excessive heat and are significant urban heat islands. Design firm Studio NAB has developed a conceptual proposal how a large big-box parking lot could be reimagined as an urban farm, with some space for charging electric cars from onsite solar panels (Figure 7). Greenhouses and fruit trees grow produce that can be supplied directly to the neighbouring store —similar to the model used by the urban farming company Gotham Greens, which grows produce in a greenhouse on top of a

Figure 7. The conceptual proposal Car Parks 2.0 transforms large carpark lots into a productive field for urban farming; by French design firm Studio NAB, 2019.

Source: Oliver Heath Design, 2019 [facebook].
https://www.facebook.com/permalink.php?id=270452799693116&story_fbid=3182678975137136

Whole Foods rooftop in New York. Some parking spaces remain— where the asphalt is replaced by green space that can help sequester CO_2 and absorb rainwater. Urban communities have not typically been associated with food production, which is mainly associated with rural spaces. Through significant technological advances (e.g., robotic farming using hydroponics), urban agriculture could possibly meet up to 10 percent of the entire food demand of urban communities and make meaningful contributions to food security, public health, urban sustainability and resilience.

Conclusions

A strategic planning approach for the integration of NBS

Spectacular eco-projects are currently popping up everywhere, and similar projects can be found in Rotterdam, Singapore and China. However, green architecture does not automatically make cities more liveable. Truly sustainable architecture must penetrate deep into the basics of buildings and cities, and fundamentally change them.

Figure 8. The two apartment towers Bosco Verticale (Vertical Forest) in Milan, Italy.

Source: Plflcn, 2019 [wikipedia, CC BY-SA 4.0]. https://en.wikipedia.org/wiki/Bosco_Verticale#/media/ File:Bosco_Verticale_Milano.jpg

The meaningful projects are often inconspicuous and less spectacular. Many of the supposed show-case buildings have to be kept operational at great expense (e.g., the additional maintenance costs for the vertical forest at the Bosco Verticale towers in Milan costs an additional monthly 1.500 Euros per apartment) (Figure 8).

Still today, due to the lack of effective urban growth boundaries, far too many suburbs are being planned and built on greenfield sites that were formerly protected green-belt land (Lehmann, 2019b). At the same time, sufficient brownfield land for urban infill and regeneration is available. For example, there would be sufficient brown-field sites for accommodating an extra million new homes in England alone, and hence there is no need to further encroach into precious greenfield land that is necessary for future recreation, biodiversity, forestry, agriculture and food supply (Campaign to Protect Rural England-CPRE, 2018). The government, developers and policy makers do still not prioritise the redevelopment of brownfield land and infill densification enough.

The urban neighbourhoods of the future will have to offer new forms of green spaces fully integrated in the existing urban fabric, including roof gardens. These will serve a dual purpose, existing both as areas for recreation whilst acting at the same time to mitigate the warmer urban microclimate. Strategic and integrated development, which concentrates on energy and water management, green infrastructure, nature-based solutions and the urban microclimate, will take a leading role in all urban development.

Strategic planning of cities shows that a basic requirement for a vibrant mixed-use quarter is population density and green space per capita. Re-greening is not a contradiction to increased densities. Green has always been part of our cities, and it can be re-introduced without leading to lower density. As the popular quarters of our compact, mixed-use 19th-century European cites show, greening the city does not need to lead to a lower density, dispersed and car-dependent city model.

The distribution of green spaces in metropolitan areas is of particular relevance, as it reveals the areas where there is a lack of green space, and in these areas easy access to green space should first be enhanced—including all categories of green space, such as parks, gardens, playgrounds, constructed wetlands, dog areas, roof gardens, and so on. Access to public parks by foot from home plays an important role. What is the percentage of inhabitants able to reach a recreational green space by foot in less than 10 minutes from home, and where are the urban areas least served?

More density can mean more green, and the experiences in reference to strategic planning approaches for NBS in Barcelona, London, Milan, Portland, New York and Melbourne have been encouraging. Finally, recommendations for the integration of NBS in the urban context have been developed that make renaturalisation an essential social and cultural dimension of urban planning for future cities. *Connecting Nature* (Innovation Action Program of 16 countries funded through the European Commission's Horizon 2020 program) has developed a framework of recommendations for the integration of NBS in the urban context to help cities navigate the path towards the large-scale implementation of nature-based solutions. The framework considers seven elements that cities need to focus on to shape their NBS (EU. Connecting Nature, 2019):

· Technical solutions.

· Governance.

· Financing and business models.

· Nature-based enterprises.

· Co-production.

· Impact assessment.

· Monitoring.

Another framework for the integration of NBS has been published by the IUCN, the "Global Standard for Nature-based Solutions: a User-friendly Framework" (IUCN, 2019), suggesting to focus on three areas:

· Design of new innovative NBS.

· Upscaling pilots by identifying gaps.

· Verifying past projects and future proposals.

These frameworks are promising and available. Research published by Steffen et al. (2018) on the *Trajectories of Earth System in the Anthropocene,* and the recent World Cities Report on *The Value of Sustainable Urbanisation*

published by UN-Habitat (2020) point all in the same direction: Our models of urbanisation will need to change and the integration of nature-based solutions will play a key role in this future change. The intrinsic value of sustainable urbanisation can and should be harnessed for the wellbeing of all. While we need specialisations, most of the complex problems in cities require interdisciplinary teams to resolve them. Clearly, what is also needed are longer-term strategies, clarity of policy, leadership and ambition of government that is followed by action adopting applied research and scientific knowledge of NBS as basis for informed decision-making.

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