10. Planning and maintaining nature-based solutions: lessons for foresight and sustainable care from Berlin, Jakarta, Melbourne, and Santiago de Chile

Rieke Hansen, Judy Bush, Didit Okta Pribadi, and Emanuel Giannotti

INTRODUCTION

Nature-based solutions (NBS) in cities raise hopes that urban green spaces will be planned and designed with ecological aspects at heart, fostering natural processes for water management or temperature regulation while benefiting both human well-being and biodiversity (Maller 2021; Raymond et al. 2017). However, NBS that often receive media attention and are promoted in political contexts include complex plantings on facades or rooftops requiring intensive care, water supply, and resources such as concrete, steel, and geotextiles. For example, the recently proclaimed largest green facade in Europe on the Kö-Bogen II commercial building in Düsseldorf consists of 8 km of hornbeam hedges in metal planters with automatic irrigation and fertilization as well as regular pruning to maintain geometric shape and size (Kraft 2020). Urban greening that has already reached the intended size when planted undermines fundamental ecological processes such as plant growth. In general, biogeochemical cycles that sustain ecosystem services are often neglected (i.e. carbon sequestration in soils), and plantings with low diversity of functional traits provide limited support for urban biodiversity (Brunbjerg et al. 2018; O'Riordan et al. 2021; Parris et al. 2018; Ziter 2016).

Certainly, high-tech greening solutions provide more ecosystem services compared to urban areas with no greening, but the benefits might be overstated and even distract from causes that need to be tackled such as CO_2 or particulate matter emissions (Keeler et al. 2019; Pataki et al. 2021). With current greenhouse gas emission levels, all trees within a city likely contribute less than

0.5 percent to climate change mitigation via carbon sequestration (Baró et al. 2014; Tang et al. 2016). It might take 26–33 years until trees reach the point of carbon neutrality and can be considered as carbon sinks (Petri et al. 2016). Moreover, the provision of ecosystem services often increases with age. Older trees provide a significantly higher amount of ecosystem services, yet urban trees are affected by high mortality rates (Rötzer et al. 2019). Thus, NBS need to be planned having the full life-cycle and required resource input in mind. Careful design and maintenance of NBS can enhance ecosystem service provision and influence sustainability. For example, maintenance intensity of green spaces and related energy use has a significant impact on the carbon footprint of these sites (Strohbach et al. 2012). Lawns represent the prime example of green elements that are often unsustainable. From an ecological perspective, lawns in their high-maintenance version, which can be found in almost any region of the world, are referred to as "green deserts" that consume ample resources yet have little habitat value (Ignatieva and Ahrné 2013). In contrast, alternatives adapted to the local climate and/or representing local biotopes, such as steppe or prairie vegetation, require fewer resources and contribute to biodiversity habitat (Ignatieva et al. 2020). The question of whether urban green space can be considered as NBS is thus very much a question of planning with natural processes and adapting to the local context.

The effects of climate change are putting increasing pressure on urban greening, reducing its ability to address urban challenges, and act as NBS. Droughts and consequently lack of access to water prevent urban vegetation from performing the intended cooling function via transpiration, or carbon sequestration via biomass growth (Gillner et al. 2014; Stratópoulos et al. 2019). Urban densification leads to additional pressure on green infrastructure by reducing available space and increased use intensities (Burgin et al. 2014; Daniel et al. 2016; Haaland and van den Bosch 2015). Green infrastructure is often not equally distributed within cities and deprived neighborhoods often suffer most from environmental pollution or the effects of climate change (Derkzen et al. 2017; Ward Thompson et al. 2016).

Efforts for planning and implementing NBS must therefore begin with basic questions: How can we preserve and/or restore existing urban green areas as well as urban trees so that they can function as NBS? How can we ensure that new NBS can actually provide the intended multiple benefits over the long term and in places where the benefits are needed most?

We shed light on these questions by sharing four case stories from different regions: major cities in Southeast Asia, southeastern Australia, Central Europe, and western South America, namely Jakarta, Melbourne, Berlin, and Santiago de Chile. We describe urban issues in these cities that have been or could be tackled with NBS, focusing on the most basic and common green elements: public green spaces and urban trees. Because of the differences in each city when it comes to green elements and whether they are considered as NBS, we refrain from a definition but try to describe the green elements in each case. We discuss how these green spaces are addressed in urban planning and the challenges of mainstreaming and maintaining NBS.

These four cases have been selected in a pragmatic approach based on contextual knowledge of the authors, aimed at providing examples for metropolitan cities in different geographic regions with different climate, planning systems, wealth, culture, and many other factors (information-oriented selection with maximum variation; Flyvbjerg 2006). For each city region major challenges of, as well as efforts for, planning and maintaining green spaces were discussed and focused on a specific topic: challenges of planning and implementing green elements in Jakarta, efforts in strategic park planning in Santiago, approaches to enhancing ecosystem service provision with blue-green infrastructure in Melbourne, and a strategy to improve maintenance in Berlin. Due to their differences, they should not be considered as comparative cases, but as examples that contribute different perspectives to the overall topic based on their local situation.

URBAN ISSUES AND POTENTIAL FOR IMPLEMENTING NATURE-BASED SOLUTIONS IN FOUR CITIES ON DIFFERENT CONTINENTS

The selected four cities from different global regions are all large metropolises with 3 to 11 million inhabitants (Table 10.1). Berlin is the only city from the Old World; it faced phases of rapid population growth already during the industrialization of the nineteenth century. Colonialization of the other regions spurred the development of settlements and cities, displacing and disrupting First Nations' and Traditional Owners' existing societies, ways of life, and custodial connections with their lands. For Jakarta, Melbourne, and Santiago, population growth strongly accelerated after the Second World War and is still high. In Berlin, after a long period of stagnation during the Cold War, population increase is a relatively recent trend.

Urbanization Pressure in Jakarta, Indonesia

Jakarta is the capital of Indonesia and drives the national economy. It is inhabited by 11 million people and deemed one of the most populous cities globally (World Population Review 2021). It contributes to 17.7 percent of the national gross domestic product (BPS-Statistic Indonesia 2020) and also plays a key role in the global economic network.

Jakarta is located in the tropical monsoon region and lies on the coast, and downstream of three watersheds, namely Citarum, Ciliwung, and Cisadane.

Table 10.1 *Comparison of the four city regions*

	Berlin, Germany	**Jakarta, Indonesia**	**Melbourne, Australia**	**Santiago de Chile, Chile**
Climate zone (Köppen climate classification)	Marine west coast	Tropical rainforest	Marine west coast	Mediterranean
Inhabitants (2018)	3.6 million	10.5 million (metro area)	4.8 million (metro area)	6.7 million (urban agglomeration)
Population development (estimated average annual rate of change in percentage for 2018–30)	+0.1	+1.6	+1.5	+0.7

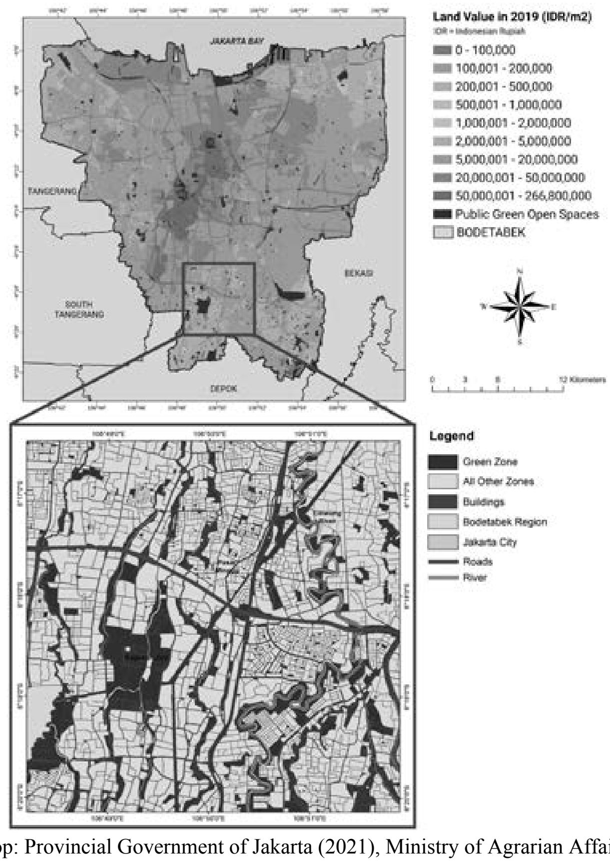
Source: Population data based on United Nations (2018).

Being sited on an alluvial plain, Jakarta is prone to flooding of its buildings and impermeable surfaces. The combination of high rainfall, land subsidence, sea-level rise, unmanaged waste and drainage, and the dominance of built-up areas increasingly raises the risk of flooding (Mishra et al. 2018; Riyando Moe et al. 2017). Based on Jakarta's land use map in 2019, vegetated areas made up only 12.3 percent of the city region (Provincial Government of Jakarta 2021).

Jakarta's hydrological cycle is mostly disrupted by urbanization and climate change effects as typically found in mega-urban Asia (Wang et al. 2020) and is progressively more threatened by flooding, drought, and land subsidence. Current planning focused on conventional engineering approaches fails in solving the issue. Despite an integrative approach to manage watersheds that involves upstream areas (peri-urban Jakarta), efforts to restore rivers, water reservoirs, and land capability to infiltrate water in Jakarta are still required. In this case, inter and transdisciplinarity of the NBS approach may offer an alternative solution. However, the concept of NBS is not yet used by urban planners in Southeast Asian cities, including Jakarta (Kooy et al. 2020; Lechner et al. 2020).

Conditions of the city's green infrastructure and lack of land accessibility

The Provincial Government of Jakarta aims to increase urban green space, as the Law of Spatial Planning Number 26/2007 mandates a minimum 30 percent of area in every city, of which 20 percent should be public and 10 percent should be private. However, until now the Government of Jakarta has only managed 5.7 percent of urban green spaces, considered public green spaces, consisting of urban forest, green lines (i.e. green open spaces along the road-side, river bank, railway side), nurseries, sports fields, cemeteries, parks, and gardens (Environmental Agency of Jakarta Province 2021). The rest is agricultural land and other green spaces managed by the private sector, which are difficult to preserve. Jakarta's public green spaces are fragmented, scattered in smaller sizes, and unevenly distributed (Figure 10.1, top).

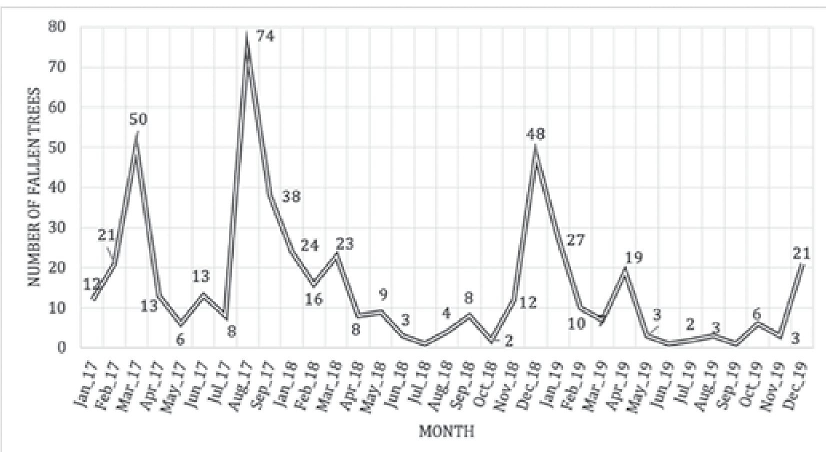


Source: Top: Provincial Government of Jakarta (2021), Ministry of Agrarian Affairs and Spatial Planning, and National Land Agency (2021); bottom: Provincial Government of Jakarta (2021); layout: K. Saifullah.

Figure 10.1 *The distribution of scarce and uneven public green spaces on different land values in Jakarta (top), and green space area lost by violation of spatial planning (bottom)*

Adding green spaces is difficult as land prices and development pressures in Jakarta are high (Figure 10.1, top). According to Setiowati et al. (2018), total land acquisition for public green space in 2012–17 was only 111.53 ha or 37.18 percent of the total target of 300 ha set by the Provincial Government of Jakarta. Moreover, the area gained was small and scattered. At the same time, there are still violations of spatial planning due to construction on public urban green spaces, as can be seen in south Jakarta (Figure 10.1, bottom).

Besides encroachment of green space, other elements of green infrastructure in Jakarta are endangered. Trees have low life expectancy mainly due to reduced growing area, unsupportive environments, and frequent rain storms. Prasetya (2014) revealed that most of the trees along the roadside in eastern Jakarta have experienced serious damage compared to the trees in a compact urban forest area, which are mostly healthy (Safitri 2018). Figure 10.2 shows the number of fallen trees from 2017 to 2019 that mainly occurred in the rainy season (i.e. August–April). Instead of protecting people from climate change effects, trees that grow on limited land adjacent to human properties have caused a lot of damage and losses, exacerbated by an increased risk of falling (Provincial Government of Jakarta 2019). Nurseries have been prepared by the government to replace fallen trees. Nevertheless, new trees need a long time to mature enough to bring ecological benefits to the city.



Source: Provincial Government of Jakarta (2019).

Figure 10.2 The number of fallen trees by month, 2017–19

The policy to provide 20 percent area for public green spaces faces huge challenges in growing cities like Jakarta with high density and land development driven by economic motives. Lack of monitoring and law enforcement as well as available budget for maintaining and extending urban green spaces have become serious issues. NBS propose a better solution as they allow the integration of natural and engineering approaches in dealing with environmental problems in Jakarta. By this integration, the advantages of green spaces in urban agendas can be well defined and developed, thus they will gain wider public support. Kooy et al. (2020) suggested an NBS approach to incorporate natural processes via green-blue space development (e.g. wetland, green walls, roof gardens, vegetated infiltration, etc.) in managing stormwater and wastewater to increase water supplies and to decrease flood risk in lowland and coastal Southeast Asian cities, especially Jakarta. However, this effort is likely hindered by rapid urbanization, typical climate conditions, especially high rainfall intensity, and poor governance that is often found in these cities (Lechner et al. 2020).

Steps Toward Greening Strategies in Santiago de Chile, Chile

The Santiago Metropolitan Area (SMA) is located in a basin whose altitude varies between 450 and 1,000 meters. The climate is Mediterranean and the annual precipitation, concentrated in winter, is scarce and varies greatly from year to year. According to climate change projections, rainfall will decrease consistently, while temperature will increase (Magrin 2015). The urbanized area has constantly grown during the last decades, consuming mainly rural land but also affecting natural areas, such as wetlands or native forest in the Andean footsteps and coastal range (Puertas et al. 2014; Romero et al. 2012). Other environmental problems include poor air quality and exposure to socio-natural disasters, like earthquakes, flooding, and forest fires (GORE RMS 2017).

The SMA is subdivided into several municipalities and lacks a metropolitan authority. This administrative fragmentation, along with the weakness of Chilean territorial planning, is a major challenge to good governance (Barton and Kopfmüller 2016; Precht et al. 2016). Although the Santiago region is the only one in Chile that has a land use plan (Plan Regulador Metropolitano de Santiago), the ministries are the main bodies responsible for infrastructure planning and implementation, with sectorial views that are rarely coordinated with one another. Moreover, the local urban regulations depend on the municipalities, which also have responsibilities in providing various services, including waste collection and green space maintenance (Giannotti et al. 2021; Vásquez et al. 2016).

Many studies have highlighted the social and spatial inequalities of the SMA, which are also evident in the distribution of green spaces, although the results differ according to the definition of green space used by each study.

The wealthiest municipalities, in the northwest cone, have a good amount of well-maintained urban forest and green space, while the rest of the city is characterized by less vegetation and poorer maintenance (Escobedo et al. 2016; Reyes and Figueroa 2010; Vásquez et al. 2017). Recent research found that municipal management is the most important variable to explain tree survival, which is consistent with the huge differences in the budget allocated by municipalities (Steinfort et al. 2020; see also Hernández and Villaseñor 2018; Reyes et al. 2015). Another relevant factor is the water requirement of trees, as drought-resistant species are more likely to survive in a semi-arid context where irrigation is required, especially during the dry season (Reyes-Paecke et al. 2019; Steinfort et al. 2020).

Investments in public green spaces

During recent years, the concern to improve the design of green spaces has grown, together with the commitment to ensure a more equitable access to them. In this regard, NBS and similar concepts, like green infrastructure, have emerged as useful approaches, but they have been mainly promoted by academic initiatives (Giannotti et al. 2021; Muñoz et al. 2019; Vásquez 2016). Within public institutions, only the Ministry of Environment (Ministerio de Medio Ambiente, MMA), has adopted these approaches, especially in the Plan for Adaptation to Climate Change and Biodiversity (MMA 2014).

The MMA is mainly concerned with peri-urban areas. In the Santiago region, the Global Environment Facility project deserves a special mention. Its primary goal is to protect biodiversity and establish corridors through the mountain ranges (https://gefmontana.mma.gob.cl/). Within the urban area, several initiatives have been promoted by the civil society, non-governmental organizations such as Fundación Mi Parque, and public institutions. Among the latter, the Ministry of Housing and Urbanism (Ministerio de Vivienda y Urbanismo, MINVU) has initiated various programs to improve the urban environments of poor neighborhoods and to realize new parks in municipalities that lack green spaces, with the aim of having more equitable access to them (Vásquez et al. 2017). MINVU can provide resources that are rarely available at the local level to design and implement new parks. Moreover, in the SMA, MINVU has also taken over their maintenance, through a specific department that now manages a network of 21 parks (Reyes et al. 2011; Figure 10.3).

In order to streamline these efforts, in 2019 MINVU began to elaborate a National Policy for Urban Parks (Politica Nacional de Parques Urbanos, PNPU). The main goals of the policy are: establishing coordination among the different stakeholders involved in the construction and maintenance of parks and securing new investments from different sources; defining criteria for a more sustainable design, especially regarding irrigation; differentiating the

Source: Copyright Cancino & Magrini and Harris & Illanes.

Figure 10.3 The "Brasil Park" in the municipality of La Granja is currently being regenerated thanks to the MINVU program for urban parks. It was designed by Cancino & Magrini and Harris & Illanes architects

uses of the parks and augmenting their safety; and concentrating investments in the municipalities with the greatest deficit of green areas.

The PNPU (2021), will probably help to advance toward a more sustainable design, better maintenance, increased participation of civil society, and more equitable distribution of green spaces in the SMA and other Chilean cities. Nevertheless, the PNPU only considers urban parks, which highlights the need to have better coordination among the many initiatives that exist today about the realization and maintenance of different green spaces and moving towards developing NBS.

Blue-Green Infrastructure Enhancement in Melbourne, Australia

Melbourne, a major city in southeastern Australia, has a population of almost 5 million and covers an area of almost 10,000 km^2 (DELWP 2017a). The city has developed from a colonial settlement in 1835 on the banks of the Yarra River. The area has been home to the Wurundjeri and Bunurong peoples, the Traditional Owners, for more than 60,000 years, and their custodianship nurtured a bountiful landscape of forests and woodlands, native grasslands, and wetlands (Presland 2008). While urbanization has decimated much of the urban area's biodiversity, Melbourne and other Australian cities continue to provide habitat to a diversity of species, including threatened species, some of which are only found in urban areas (Ives et al. 2013, 2016; Soanes and Lentini 2019).

Melbourne's green-blue spaces are located in a network of parks, gardens, nature reserves, golf courses, and waterways (Figure 10.4), as well as street plantings and private gardens (VEAC 2011). Melbourne's livability and sustainability is threatened by the urbanization pressures of densification (reducing open space) and expansion (with suburbs replacing the peri-urban forests and agricultural areas on the urban fringes) (TNC and RM 2019). In the competition for urban space, infrastructure provision such as transport is often prioritized, with green space and trees assumed to be easy to replace, relocate, or even "offset" (through land purchase outside the city boundaries). These challenges are exacerbated by climate change: increasingly severe and frequent heatwaves, drought, and extreme weather events (TNC and RM 2019). A record-breaking heatwave in February 2009, in which more than 370 people died from heat impacts, was the precursor to catastrophic bushfires that burnt into Melbourne's fringes, killing 183 people (Steffen et al. 2014).

As Melbourne's planners increasingly recognize the threats and impacts of urban heat, "cooling and greening" the city has become a key priority (DELWP 2017a). While the term "nature-based solutions" is not yet widely used by planners and practitioners in Australia (Moosavi et al. 2021), there is increasing recognition of the critical roles that well-watered landscapes play in both cooling urban areas and providing habitat biodiversity, treating air and water runoff, and providing opportunities for people's connection with nature (DELWP 2019; TNC and RM 2019).

Developing blue-green infrastructure

Melbourne's 2017 metropolitan strategic plan highlights the contribution to urban resilience provided by the cooling benefits of a greener city (DELWP 2017a). The implementation of the plan's greening policy includes mapping the trees and green spaces in the city, creating guidelines for streetscape planting and design and partnering with research institutions, local governments, and others to facilitate and support implementation of green roofs, and other urban blue-green infrastructures (DELWP 2021).

One of these implementation partners is Greening the West, a regional collaboration of state government, local governments, community organizations, universities, and industry bodies, initiated and facilitated by urban water utility City West Water (GTW 2020). The rapidly urbanizing western areas of Melbourne are significantly drier and hotter than other areas of the city. Greening the West formed in 2011, to increase the amount of urban greening as well as to improve the quality and use of green spaces. One of the key initiatives,

Note: During Melbourne's COVID-19 pandemic lockdown, spaces such as golf courses, usually the exclusive domain for golfers (as well as an important habitat for biodiversity), were opened to provide valued "breathing space" for local residents and adventure space for children.
Source: Judy Bush (October, 2020).

Figure 10.4 Bracken Creek flows through a golf course in Melbourne's inner north

"Greening the Pipeline," aims to both revegetate and open up access to a 27 km decommissioned water pipeline easement.

While NBS, in the form of "green infrastructure" and "water-sensitive urban design," are increasingly highlighted by Melbourne's planners as priorities, key challenges remain for their implementation and maintenance at scale, including allocating space for NBS in a densifying city, and adequately resourcing ongoing maintenance. As the number and diversity of water-sensitive urban design and green infrastructure installations increase, there is also an increase in knowledge and information on maintenance requirements and techniques

(DELWP 2017b; MWC 2013a), including provision of training courses and seminars for technicians, planners, and maintenance staff (Clearwater 2021). However, there are significant challenges associated with maintenance, particularly of water-sensitive urban design treatments if the installations have not been designed with a view to ongoing maintenance. For example, the sediment collection function of installations requires periodic sediment removal, which can be expensive and technically difficult, and which may involve disposal of contaminated waste if the stormwater has carried higher levels of pollutants (MWC 2013b). Furthermore, stormwater wetlands which have accumulated pollutants can create "ecological traps" for native frogs and fish, impacting their health and ongoing survival and further highlighting the need for a focus on effective design and maintenance regimes (Hale et al. 2019).

While guidelines and technical checklists emphasize the importance of ongoing, regular maintenance, policy officers have noted that although funding may be available for "capital expenditure" for new installations, operational budgets are often under pressure, and rarely increased, even with an increase in areas to be maintained (Bush 2020).

Green Space Maintenance Challenges in Berlin, Germany

Berlin is the capital of Germany and now the most populous city in the European Union. About 40 percent of the city consists of green and blue spaces including large forests, water bodies, and agricultural land in the peri-urban zone (GRIS 2020). The population in the central districts does not have adequate access to nearby green spaces (SenStadtUM 2016b, appendix). Continued population growth increases pressure to densify and develop new residential areas leading to higher intensity of use for Berlin's green infrastructure (SenUVK 2019). The effects of climate change lead to additional pressure on the urban vegetation. The city is expected to be more frequently exposed to extensive dry spells as well as cloudbursts leading to flooding (SenStadtUM 2016a).

The concept of NBS so far has received little attention in German city planning, although many practices such as decentralized rainwater management have a long tradition (Zölch et al. 2016). Moreover, Berlin builds on 150 years of green space planning, is frequently lauded for ecological planning approaches, and has a broad variety of plans and policies concerned with green infrastructure (Hansen and Pauleit 2020). Public green spaces of about 11,000 ha and 440,000 street trees are managed by 12 District Street and Green Space Offices, while protected habitats and nature reserves are managed by District Environment and Nature Conservation Offices (Ruddeck and Schahin 2017). Green spaces are often in poor condition and, compared to other major German cities, Berlin residents feel least safe and are least content with the maintenance of green spaces (Forsa 2014). Between 2012 and 2019, about 44,000 street trees were cut and only about 18,000 planted (BUND 2021). Issues with maintenance even concern relatively new green spaces, partly due to high intensity of use, but also due to climatic conditions, plant diseases, etc. For example, in the landscape park Johannisthal (see Figure 10.5) more than 500 of the 870 planted native trees died within the first ten years. According to the district administration, this is related to the low water storage capacity of the soil, high surface temperatures, and tree species not being adapted to the extreme site conditions. Irrigation, which is not automated, was applied but did not significantly stop the loss of trees and resulted in high costs. Therefore, replanting is not planned (BA Treptow-Köpenick 2018a, 2018b).

Note: While the park includes a nature reserve and is a biodiversity hotspot for grassland species, a large proportion of the newly planted trees died, despite irrigation, leading to a lack of shadow and cooling capacity.
Source: Rieke Hansen (2013).

Figure 10.5 Landscape park Altes Flugfeld Johannisthal in Berlin is a former airfield with extreme site conditions

Berlin's "Good care manual" as a pathway to improved maintenance

Berlin's city administration developed a manual for good care ("Handbuch Gute Pflege") which defines standards for different green elements such as street trees, ornamental plantings, or lawns (SenUVK 2017). The goal was to combine quality requirements for recreation, cultural heritage, and nature conservation, and the development processes of the manual involved both offices from streets and green spaces as well as environment and nature conservation. The manual links information on habitat management with maintenance data in Berlin's digital green space information system "GRIS."

Eleven "golden rules" for maintenance include step-wise mowing or pruning to create a habitat mosaic, planting of forage plants for pollinators, enhancement of structural diversity, or allowing succession. The manual's catalogue of green elements provides detailed information, including social, ecological and aesthetic functions, maintenance tasks, ecological information (i.e. relevance as a habitat for protected species), and a calendar with appropriate periods of the year for each task.

An overarching aim is to foster ecological maintenance approaches if in correspondence with recreational needs and historic relevance. For example, if a lawn is used less, the maintenance shall be reduced. The manual also refers to monitoring in order to ensure the long-term vitality of urban green elements, especially with respect to climate change effects. For restoration and replanting, measures are suggested that enhance the vitality such as selecting drought-resistant street trees or more robust plants for lawns. Currently, the applicability of the manual is tested with pilot projects that either have a social, ecological or historic-aesthetic focus in all 12 districts (SenUVK 2021). The manual represents a shared standard for all of Berlin's districts, shall help to consider maintenance requirements during the planning of new green spaces, illustrate the economic damage of poor maintenance and overall provide an argumentation base to argue for sufficient resources. Digital green space management helps to use resources efficiently and monitor maintenance activities. The manual is considered as an important first step in a path towards better green space maintenance in Berlin and will also be used for political and public communication in order to increase the awareness of the value of sustainable green space management (Ruddeck and Schahin 2017).

CHALLENGES ACROSS THE CITIES

Despite their differences in biogeographic, socio-economic, and cultural contexts, the four cities share a number of aspects relevant for implementing NBS, including barriers. It should be noted that the focus was not on the full spectrum of NBS but on public green spaces and urban trees as important elements of urban green infrastructure. Considering that NBS are supposed to provide a variety of ecosystem services and contribute to biodiversity, not all urban green spaces might qualify as NBS but they do represent an important spatial resource in cities that has the potential to be carefully developed to provide more and more diverse ecosystem services and to be sustained over the long term.

Pressures on and Maintenance Issues with the Existing Green Infrastructure

All cities face severe effects of climate change, which threaten human health and economic assets but also the health and survival of vegetation. Climatic change increases the need for NBS for cooling or flood retention yet at the same time increases stress on vegetation and drives failure rates. For example, fragmented small green spaces make trees vulnerable to storms in Jakarta. In Melbourne, with hot, dry summers and increasing exposure to severe droughts, ensuring adequate water for healthy vegetation is critical. Water scarcity leads to conflicts between water usage for urban vegetation and needs for drinking water. In Berlin, droughts require costly watering which is not standard practice, and conflicts related to water shortage are expected to increase. Maintenance, including irrigation, or lack thereof, is a crucial factor for the survival of trees in Santiago and leads to unequal distribution of green infrastructure in correspondence with municipal wealth. Besides, maintenance issues are expected to become more urgent with progressing climate change.

Overall, all four cities struggle to maintain existing green infrastructure, and their efforts in expanding green areas and planting trees are partly exceeded by loss, such as with street trees in Berlin or when (illegal) urban development happens in Jakarta. Moreover, public investments can be undermined by the loss of vegetation from private land as in Melbourne. All these issues can contribute to a gradual degradation and net loss of green infrastructure. Moreover, loss of mature habitats or large trees take decades to be compensated (Le Roux et al. 2014). Therefore, maintaining the existing green infrastructure is paramount.

Challenges for Implementing Sustainable Nature-Based Solutions

Barriers to implementing NBS relate to land accessibility, which becomes even more difficult when urbanization pressure is high. This concerns all four cities but is especially evident in Jakarta. Efforts to increase green infrastructure have been pushed to reduce flood risk, but are hampered by the lack of land availability and high land prices in Jakarta. Moreover, all four cities face pressure on green and open spaces due to urbanization. In newly developed areas as well as densified quarters, space for trees and other larger vegetation is usually limited (Erlwein and Pauleit 2021), leaving few options to design NBS that address societal challenges as well as biodiversity and/or those requiring

NBS with a high level of technology, including related resource input and intensive maintenance such as high-tech green roofs (Snep et al. 2020).

In Santiago, Melbourne, and Berlin, programs are available for creating green and blue spaces, such as through regional partnerships like Greening the West in the Melbourne region, nature compensation requirements in Berlin, or the urban parks program in Santiago. However, if maintenance issues are not addressed such investments can prove to be unsustainable, providing opportunities for high-profile ribbon-cutting events but no long-term benefit. Moreover, without long-term financing, funding programs can only be accessed by municipalities and districts that are well off and can afford additional maintenance resources, as in the Santiago region, resulting in unequal distribution of NBS.

WAYS FORWARD FOR MAINSTREAMING NATURE-BASED SOLUTIONS

Mechanisms and approaches for mainstreaming NBS are highly context-specific, making it difficult to propose generalizable recommendations. Different contexts in different cities as well as different planning tasks require adapted measures (i.e. for conservation, restoration, or new development of urban green and blue spaces). In the four analyzed cities, the concept of NBS is not yet explicitly applied in planning but there is awareness of the benefits that could be provided by NBS and there are efforts to utilize these benefits. To support mainstreaming and maintaining of NBS, we can conclude the following.

Legal and Political Frameworks for Protecting and Implementing Nature-Based Solutions

Mainstreaming NBS requires effective planning instruments and regulations which ensure that pressure of urban expansion, densification, and economic interest do not outcompete interest in providing NBS. For cities like Jakarta, it is not only important to enlarge green spaces but also to monitor and control spatial violations on the reserved (public) green spaces. This requires political as well as legal support, i.e. via planning codes or regulations that require integration of NBS into the new developments such as green area factors (Climate ADAPT 2020; Juhola 2018). Moreover, it needs a public administration with capacity for monitoring to ensure that planned NBS are really implemented and maintained.

Nature-Based Solutions Planning with Foresight

The environmental stress caused by increasingly frequent and severe drought and reduced water availability, rising temperatures, and catastrophic events (Kendal et al. 2018) has implications for plant suitability and conservation of endemic and threatened species. "Novel ecosystems" and "climate analogues" should be considered to develop NBS that are better adapted to future climate conditions at the same time as supporting local biodiversity (Parris et al. 2020). Strategic approaches to maintenance such as the "Good care manual" in Berlin help to promote green elements that qualify as NBS and provide guidance and foresight. If maintenance supported by life-cycle assessments is already considered during planning, NBS can be long-lasting and responsive to future change.

Considering Scale, Design, and Distribution of Nature-Based Solutions to Optimize the Benefits

Small green spaces and unequal distribution as in Jakarta and Santiago not only lower the benefits and just distribution but also, particularly in Jakarta, increase the risk of fallen trees and higher maintenance costs caused by limited spaces for tree growth. In Santiago, tree survival is difficult to ensure in municipalities with less vegetation and poor maintenance, usually related to lack of financial resources. NBS should be an important element of city master plans but also at district- and site-level planning to ensure strategic integration of NBS and reserving sufficient space. Also, the resource needs for maintenance and the economic-ecological benefits for the city need to be properly measured regarding scale, design, and distribution of NBS.

Prioritization of Nature-Based Solutions with High Social and Ecological Benefits and High Biodiversity Value

A priority should be given to NBS with long-term ecological functioning and contribution to biodiversity as well as providing benefits to citizens that need them most. The Berlin case is an example of how to consider aesthetics, usability, and ecological aspects of NBS. Part of investing in long-term well-being of green infrastructure is providing conditions for healthy vegetation growth, such as trees with adequate access to soil and water, as well as professional maintenance that ensure ongoing functioning, as in Melbourne. In addition, planners should prioritize districts with a lack of public green spaces, as in Santiago.

Retrofitting to Create Sustainable Nature-Based Solutions

Many existing urban green or blue elements would not qualify as NBS because they provide only limited benefits or low support for biodiversity, and the required resource input or use of environmentally damaging materials might even exceed the benefits, such as with intensive lawns. However, these elements can be transformed into NBS by adapted maintenance or replanting to enhance habitat function and the provision of ecosystem services. Berlin's "Good care manual" shows a way towards a gradual transition by including rules for more sustainable and biodiversity-friendly maintenance that is supposed to be enhanced. Regeneration and restoration programs as described for Santiago and Melbourne can promote sustainable solutions and adaptation to climatic conditions by using locally adapted vegetation types that ensure longevity and low maintenance needs. Tree programs as in Jakarta should not only replant but also improve living conditions for mature trees such as enhancing root space, reducing soil compaction, and improving stormwater infiltration for supplying trees.

Resource Input Balanced with Nature-Based Solutions Benefits

For all NBS and in particular high-tech solutions including electronically monitored systems, costs and resource consumption should be checked against the benefits with life-cycle assessments in order to invest in the most sustainable NBS. As the climate changes, resource input may need to be reevaluated, such as with irrigation in Berlin. Drought-resistant trees can survive water scarcity but might provide limited ecosystem services, such as cooling via shading if growth is hindered by water shortages, so investments in irrigation systems may be warranted. In the context of water scarcity, conflicting demands for water need to be considered and, eventually, technical solutions for water access are needed (i.e. use of greywater from households) in cities like Melbourne that focus on water-sensitive urban design and emphasize the importance of blue spaces for cooling.

Sustained Commitment for Long-Term Care

The mainstreaming of NBS, as living dynamic systems, requires provision of ongoing operational funding for maintenance, not just construction funding. Long-term maintenance requires commitment to and investment in resources and skills (Bush 2020). Acknowledging the dynamic nature of NBS and landscape maintenance means that ongoing management must be adaptive, requiring careful monitoring and evaluation, as well as incorporating mechanisms to adjust with changing conditions, community priorities, and environmental factors as shown by the cases of Berlin and Melbourne. As can be learned from Jakarta, lack of maintenance, monitoring, and evaluation can undermine violations of public green spaces and increase the risk of fallen trees.

Enhancing Public Participation

In Santiago, Melbourne, and Berlin participation of public and non-government stakeholders enhanced the management of green-blue spaces. Both public and private green spaces are important for providing NBS. In cities like Jakarta, where land acquisition by the government is difficult, private landowners could be taken more into focus. This requires planning instruments that can range from incentives to obligations for private landowners. However, it needs to be considered that private persons might lack awareness or resources for proper maintenance and might have interest in urban greening not in line with professional motivations for implementing NBS. Thus, involving non-governmental stakeholders requires negotiation of different interests. Also, for NBS on public land, participation should be enhanced to ensure that citizens' needs are met.

REFERENCES

BA Treptow-Köpenick. (2018a). Beantwortung der Schriftlichen Anfrage SchA VIIII0503 vom 30.05.2018 der Bezirksverordneten Dr. Claudia Schlaak-Bündnis 90 I Die Grünen [Response to the written question SchA VIIII0503 of 30.05.2018 by District Councillor Dr. Claudia Schlaak-Bündnis 90 I Die Grünen], accessed 31 March 2021 at https://fraktion-gruene-treptow-koepenick.de/wp-content/uploads/sites/3/2020/04/0503SchAAntwort.pdf

BA Treptow-Köpenick. (2018b). Beantwortung der Schriftlichen Anfrage SchA Vlll/0580 vom 21.08.2018 der Bezirksverordneten Dr. Claudia Schlaak-Bündnis 90/ Die Grünen [Response to the written question SchA VIIII0503 of 21.08.2018 by District Councillor Dr. Claudia Schlaak-Bündnis 90 I Die Grünen], accessed 31 March 2021 at https://fraktion-gruene-treptow-koepenick.de/wp-content/uploads/sites/3/2020/04/0580SchAAntwort.pdf

Baró, F., L. Chaparro, E. Gómez-Baggethun, J. Langemeyer, D.J. Nowak, and J. Terradas. (2014). Contribution of Ecosystem Services to Air Quality and Climate Change Mitigation Policies: The Case of Urban Forests in Barcelona, Spain. *AMBIO, 43*(4), 466–479.

Barton, J.R. and J. Kopfmüller. (2016). *Santiago 2030: Escenarios para la planificacion estrategica*. Santiago de Chile: RIL editores.

BPS-Statistic Indonesia. (2020). *Gross Regional Domestic Product of Provinces in Indonesia by Industry 2015–2019*. Jakarta.

Brunbjerg, A.K., J.D. Hale, A.J. Bates, R.E. Fowler, E.J. Rosenfeld, and J.P. Sadler. (2018). Can patterns of urban biodiversity be predicted using simple measures of green infrastructure? *Urban Forestry & Urban Greening*, *32*, 143–153.

BUND. (2021). BUND Baumreport. Berlin 2012–2019, accessed 31 March 2021 at www.bund-berlin.de/fileadmin/berlin/publikationen/Naturschutz/baeume/Baumreport_12-19.pdf

Burgin, S., C. Parissi, and T. Webb. (2014). The unintended consequences of government policies and programmes for public open spaces in inner-urban Sydney. *International Journal of Environmental Studies*, *71*(2), 154–166.

Bush, J. (2020). The role of local government greening policies in the transition towards nature-based cities. *Environmental Innovation and Societal Transitions*, *35*, 35–44.

Clearwater. (2021). Building capacity for integrated water management, accessed 29 June 2021 at www.clearwatervic.com.au/

Climate ADAPT. (2020). Berlin Biotope area factor: Implementation of guidelines helping to control temperature and runoff, accessed 3 March 2021 at https://climate-adapt.eea.europa.eu/metadata/case-studies/berlin-biotope-area-factor-2013-implementation-of-guidelines-helping-to-control-temperature-and-runoff

Daniel, C., T.H. Morrison, and S. Phinn. (2016). The governance of private residential land in cities and spatial effects on tree cover. *Environmental Science & Policy*, *62*, 79–89.

DELWP. (2017a). *Plan Melbourne 2017–2050. Metropolitan Planning Strategy*. Melbourne: Victorian Department of Environment, Land, Water and Planning.

DELWP. (2017b). *Planning a Green-Blue City*. Melbourne: Victorian Department of Environment, Land, Water and Planning.

DELWP. (2019). *Trees for Cooler and Greener Streetscapes: Guidelines for Streetscape Planning and Design*. Melbourne: Victorian Department of Environment, Land, Water and Planning.

DELWP. (2021). Cooling and greening Melbourne: Green infrastructure to create more liveable and climate-adapted communities, accessed 29 June 2021 at www.planning.vic.gov.au/policy-and-strategy/planning-for-melbourne/plan-melbourne/cooling-greening-melbourne

Derkzen, M.L., H. Nagendra, A.J.A. van Teeffelen, A. Purushotham, and P.H. Verburg. (2017). Shifts in ecosystem services in deprived urban areas: Understanding people's responses and consequences for well-being. *Ecology and Society*, *22*(1), 51.

Environmental Agency of Jakarta Province. (2021). Informasi Ruang Terbuka Hijau Provinsi DKI Jakarta [Green open spaces information of DKI Jakarta province], accessed 15 February 2021 at https://jakartasatu.jakarta.go.id/portal/apps/experiencebuilder/experience/?id=aa91a84fab5b4f0caa554398793d1ab4

Erlwein, S. and S. Pauleit. (2021). Trade-offs between urban green space and densification: Balancing outdoor thermal comfort, mobility, and housing demand. *Urban Planning*, *6*(1), 5–19.

Escobedo, F., S. Palmas-Perez, C. Dobbs, S. Gezan, and J. Hernandez. (2016). Spatio-temporal changes in structure for a Mediterranean urban forest: Santiago, Chile 2002 to 2014. *Forests*, *7*(12), 121.

Flyvbjerg, B. (2006). Five misunderstandings about case-study research. *Qualitative Inquiry*, *12*(2), 219–245.

Forsa (2014). Zufriedenheit mit urbanem Grün in deutschen Großstädten [Satisfaction with urban green space in major German cities], accessed 31 March 2021 at https://taspo.de/fileadmin/news_import/forsa-Umfrage_2014.pdf

Giannotti, E., A. Vásquez, E. Galdamez, P. Velásquez, and C. Devoto. (2021). Planificación de infraestructura verde para la emergencia climática. Aprendizajes desde el proyecto "Stgo+," Santiago de Chile. *Cuadernos de Geografía: Revista Colombiana de Geografía*, *30*(2), 359–375.

Gillner, S., A. Bräuning, and A. Roloff. (2014). Dendrochronological analysis of urban trees: Climatic response and impact of drought on frequently used tree species. *Trees*, *28*(4), 1079–1093.

GORE RMS (Gobierno Regional Metropolitano de Santiago). (2017). Santiago humano y resiliente. Santiago de Chile.

GRIS. (2020). Anteil öffentlicher Grünflächen in Berlin [Share of public green spaces in Berlin], accessed 31 March 2021 at www.berlin.de/senuvk/umwelt/stadtgruen/gruenanlagen/de/daten_fakten/downloads/ausw_5.pdf

GTW. (2020). Strategic plan 2020–2025: A regional approach to delivering community health and wellbeing, accessed 29 June 2021 at https://greeningthewest.org.au/wp-content/uploads/2020/12/GTW-StrategicPlan2020-2050-v23.pdf

Haaland, C. and C.K. van den Bosch. (2015). Challenges and strategies for urban green-space planning in cities undergoing densification: A review. *Urban Forestry & Urban Greening*, *14*(4), 760–771.

Hale, R., S.E. Swearer, M. Sievers, and R. Coleman. (2019). Balancing biodiversity outcomes and pollution management in urban stormwater treatment wetlands. *Journal of Environmental Management*, *233*, 302–307.

Hansen, R. and S. Pauleit. (2020). Planning multifunctional urban green infrastructure for compact cities in Europe, in J.H. Breuste, M. Artmann, C.I. Iojă, and S. Qureshi (eds), *Making Green Cities: Concepts, Challenges and Practice, 2nd Edition*. Cham: Springer, pp. 493–503.

Hernández, H.J. and N.R. Villaseñor. (2018). Twelve-year change in tree diversity and spatial segregation in the Mediterranean city of Santiago, Chile. *Urban Forestry & Urban Greening*, *29*, 10–18.

Ignatieva, M. and K. Ahrné. (2013). Biodiverse green infrastructure for the 21st century: From "green desert" of lawns to biophilic cities. *Journal of Architecture and Urbanism*, *37*(1), 1–9.

Ignatieva, M., D. Haase, D. Dushkova, and A. Haase. (2020). Lawns in cities: From a globalised urban green space phenomenon to sustainable nature-based solutions. *Land*, *9*(3), 73.

Ives, C.D., R. Beilin, A. Gordon, D. Kendal, A.K. Hahs, and M.J. McDonnell. (2013). Local assessment of Melbourne: The biodiversity and social-ecological dynamics of Melbourne, Australia, in T. Elmqvist, M. Fragkias, J. Goodness, B. Güneralp, P.J. Marcotullio, R.I. McDonald et al. (eds), *Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities*. Dordrecht: Springer, pp. 385–407.

Ives, C.D., P.E. Lentini, C.G. Threlfall, K. Ikin, D.F. Shanahan, G.E. Garrard et al. (2016). Cities are hotspots for threatened species. *Global Ecology and Biogeography*, *25*(1), 117–126.

Juhola, S. (2018). Planning for a green city: The green factor tool. *Urban Forestry & Urban Greening*, *34*, 254–258.

Keeler, B.L., P. Hamel, T. McPhearson, M.H. Hamann, M.L. Donahue, K.A. Meza Prado et al. (2019). Social-ecological and technological factors moderate the value of urban nature. *Nature Sustainability*, *2*(1), 29–38.

Kendal, D., Dobbs, C., Gallagher, R.V., Beaumont, L.J., Baumann, J., Williams, N.S.G., and Livesley, S.J. (2018). A global comparison of the climatic niches of urban and native tree populations. *Global Ecology and Biogeography*, *27*(5), 629–637.

Kooy, M., K. Furlong, and V. Lamb. (2020). Nature based solutions for urban water management in Asian cities: Integrating vulnerability into sustainable design. *International Development Planning Review*, *42*(3), 381–390.

Kraft, B. (2020). Fassade als lebendiges Grün: Kö-Bogen II, Düsseldorf. *Deutsche Bauzeitschrift*, 09.
Le Roux, D.S., K. Ikin, D.B. Lindenmayer, A.D. Manning, and P. Gibbons. (2014). The future of large old trees in urban landscapes. *PLoS ONE*, *9*(6), e99403.
Lechner, A.M., R.L. Gomes, L. Rodrigues, M.J. Ashfold, S.B. Selvam, E.P. Wong et al. (2020). Challenges and considerations of applying nature-based solutions in low- and middle-income countries in Southeast and East Asia. *Blue-Green Systems*, *2*(1), 331–351.
Magrin, G. (2015). *Adaptación al cambio climático en América Latina y el Caribe*. Santiago de Chile: Naciones Unidas.
Maller, C. (2021). Re-orienting nature-based solutions with more-than-human thinking. *Cities*, *113*, 103155.
Ministry of Agrarian Affairs and Spatial Planning and National Land Agency (2021). Map of Land Value Zone 2019, accessed 15 February 2021 at https://bhumi.atrbpn.go.id.
Mishra, B.K., A. Rafiei Emam, Y. Masago, P. Kumar, R.K. Regmi, and K. Fukushi. (2018). Assessment of future flood inundations under climate and land use change scenarios in the Ciliwung River Basin, Jakarta. *Journal of Flood Risk Management*, *11*, S1105–S1115.
MMA (Ministerio de Medio Ambiente). (2014). *Plan de adaptación al cambio climático en biodiversidad*. MMA: Santiage, Chile.
Moosavi, S., G.R. Browne, and J. Bush. (2021). Perceptions of nature-based solutions for Urban Water challenges: Insights from Australian researchers and practitioners. *Urban Forestry & Urban Greening*, *57*, 126937.
Muñoz, J.C., J. Barton, J., D. Frías, A. Godoy, W. Bustamante, S. Cortés, M. Munizaga, C. Rojas, and E. Wegemann. (2019). *Ciudades y cambio climático en Chile: recomendaciones desde la evidencia científica*. Santiago de Chile: Comité Científico COP25, Ministerio de Ciencia, Tecnología, Conocimiento e Innovación.
MWC. (2013a). WSUD maintenance guidelines: inspection and maintenance activities, accessed 29 June 2021 at www.melbournewater.com.au/media/635/download
MWC. (2013b). Resetting sediment ponds: best practice guide: Frog Hollow at Eumemmerring Creek, Hallam, accessed 29 June 2021 at www.melbournewater.com.au/media/602/download
O'Riordan, R., J. Davies, C. Stevens, J.N. Quinton, and C. Boyko (2021). The ecosystem services of urban soils: A review. *Geoderma*, *395*, 115076.
Parris, K.M., M. Amati, S.A. Bekessy, D. Dagenais, O. Fryd, A.K. Hahs et al. (2018). The seven lamps of planning for biodiversity in the city. *Cities*, *83*, 44–53.
Parris, K.M., B.S. Barrett, H.M. Stanley, and J. Hurley (eds). (2020). *Cities for People and Nature*. Melbourne: Clean Air and Urban Landscapes Hub.
Pataki, D.E., M. Alberti, M.L. Cadenasso, A.J. Felson, M.J. McDonnell, S. Pincetl, R.V. Pouyat, H. Setälä, and T.H. Whitlow. (2021). The benefits and limits of urban tree planting for environmental and human health. *Frontiers in Ecology and Evolution*, *9*, 603757.
Petri, A.C., A.K. Koeser, S.T. Lovell, and D. Ingram. (2016). How green are trees? Using life cycle assessment methods to assess net environmental benefits. *Journal of Environmental Horticulture*, *34*(4), 101–110.
Prasetya, B. (2014). Upaya menurunkan resiko pohon tumbang [Efforts to reduce a risk of fallen trees]. *Risalah Kebijakan Pertanian dan Lingkungan*, *1*(1), 7–11.

Precht, A., S. Reyes, and C. Salamanca. (2016). *El ordenamiento territorial en Chile*. Santiago de Chile: Ediciones Universidad Católica de Chile, Vicerrectoría de Comunicaciones.
Presland, G. (2008). *The Place for a Village: How Nature Has Shaped the City of Melbourne*. Melbourne: Museum Victoria Publishing.
Provincial Government of Jakarta. (2019). Pohon Tumbang di DKI Jakarta [Falling trees in DKI Jakarta], accessed 15 February 2021 at https://statistik.jakarta.go.id/pohon-tumbang-di-dki-jakarta
Provincial Government of Jakarta. (2021). Jakarta's land use map 2021, accessed 15 February 2021 at https://jakartasatu.jakarta.go.id/portal/apps/webappviewer/index.html?id=1c1bfcced2cb4852bbeaefcd968a6d04
Puertas, O.L., C. Henríquez, and F.J. Meza. (2014). Assessing spatial dynamics of urban growth using an integrated land use model: Application in Santiago Metropolitan Area, 2010–2045. *Land Use Policy*, *38*, 415–425.
Raymond, C.M., N. Frantzeskaki, N. Kabisch, P. Berry, M. Breil, M.R. Nita, D. Geneletti, and C. Calfapietra. (2017). A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas. *Environmental Science & Policy*, *77*, 15–24.
Reyes, S. and I.M. Figueroa. (2010). Distribución, superficie y accesibilidad de las áreas verdes en Santiago de Chile. *EURE (Santiago)*, *36*(109), 89–110.
Reyes, S., M. Ibarra, M. Miranda, A. Precht, and C. Salamanca. (2011). Institucionalidad para la creación, mantención y conservación de parques urbanos, in I. Irarrázaval and E. Puga (eds), *Propuestas para Chile. Concurso Políticas Públicas*. Santiago de Chile: Centro de Políticas Públicas UC, pp. 145–172.
Reyes, S., F. De la Barrera, C. Dobbs, C. Pavez, and A. Spotorno. (2015). Costos de mantención de las áreas verdes urbanas en Chile. Santiago de Chile: Ministerio de Vivienda y Urbanismo, accessed 3 March 2021 at http://observatoriodoc.colabora.minvu.cl/Documentos%20compartidos/ESTUDIOS%20OBSERVATORIO/IFinal-Costoareas-verdes-PUC.pdf
Reyes-Paecke, S., J. Gironás, O. Melo, S. Vicuña, and J. Herrera. (2019). Irrigation of green spaces and residential gardens in a Mediterranean metropolis: Gaps and opportunities for climate change adaptation. *Landscape and Urban Planning*, *182*, 34–43.
Riyando Moe, I., S. Kure, N. Fajar Januriyadi, M. Farid, K. Udo, S. Kazama, and S. Koshimura. (2017). Future projection of flood inundation considering land-use changes and land subsidence in Jakarta, Indonesia. *Hydrological Research Letters*, *11*(2), 99–105.
Romero, H., A. Vásquez, C. Fuentes, M. Salgado, A. Schmidt, and E. Banzhaf. (2012). Assessing urban environmental segregation (UES): The case of Santiago de Chile. *Ecological Indicators*, *23*, 76–87.
Rötzer, T., M.A. Rahman, A. Moser-Reischl, S. Pauleit, and H. Pretzsch. (2019). Process based simulation of tree growth and ecosystem services of urban trees under present and future climate conditions. *Science of the Total Environment*, *676*, 651–64.
Ruddeck, K. and H. Schahin. (2017). Pflegestandards für die Berliner Grünflächen und Freiflächen: Das "Handbuch Gute Pflege" [Maintenance standards for Berlin's green spaces and open spaces: The "Good maintainance manual"], *Stadt + Grün*, 6. https://stadtundgruen.de/artikel/das-handbuch-gute-pflege-6974.html
Safitri, H.M. (2018). *Kesehatan pohon di hutan kota Cijantung, Jakarta Timur* [Tree health in Cijantung urban forest area, east Jakarta]. Bachelor thesis, IPB University, Bogor.

SenStadtUM. (2016a). Adapting to the impacts of climate change in Berlin – AFOK: Executive summary, accessed 3 March 2021 at www.berlin.de/sen/uvk/klimaschutz/anpassung-an-den-klimawandel/programm-zur-anpassung-an-die-folgen-des-klimawandels/

SenStadtUM. (2016b). Landschaftsprogramm. Artenschutzprogramm 2016 [Landscape programme: Species protection programme 2016], accessed 3 March 2021 at www.berlin.de/sen/uvk/natur-und-gruen/landschaftsplanung/landschaftsprogramm/

SenUVK. (2017). Handbuch Gute Pflege: Pflegestandards für die Berliner Grün- und Freiflächen [Manual for good care: Maintenance standards for Berlin's green and open spaces], accessed 3 March 2021 at www.berlin.de/senuvk/umwelt/stadtgruen/pflege_unterhaltung/download/Handbuch-Gute-Pflege_Berlin_Druck.pdf

SenUVK. (2019). Gesamtstädtische Ausgleichskonzeption: Auf dem Weg zum Berliner Ökokonto [City-wide compensation concept: On the way to the Berlin eco-account], accessed 3 March 2021 at www.berlin.de/sen/uvk/natur-und-gruen/landschaftsplanung/landschaftsprogramm/gesamtstaedtische-ausgleichskonzeption/

SenUVK. (2021). Übersicht der Pilotprojekte – Handbuch Gute Pflege (HGP) [Overview of pilot projects: Manual of good care], accessed 31 March 2021 at www.berlin.de/senuvk/umwelt/stadtgruen/pflege_unterhaltung/de/hgp/karte.shtml

Setiowati, R., H.S. Hasibuan, and R.H. Koestoer. (2018). Green open space masterplan at Jakarta Capital City, Indonesia for climate change mitigation. *IOP Conference Series: Earth and Environmental Science*, *200*, 12042.

Snep, R.P.H., J.G. Voeten, G. Mol, and T. van Hattum. (2020). Nature based solutions for urban resilience: A distinction between no-tech, low-tech and high-tech solutions. *Frontiers in Environmental Science*, *8*, 599060.

Soanes, K. and P.E. Lentini. (2019). When cities are the last chance for saving species. *Frontiers in Ecology and the Environment*, *17*(4), 225–231.

Steffen, W., L. Hughes, and S. Perkins. (2014). Heatwaves: hotter, longer, more often. Australia, accessed 3 March 2021 at www.climatecouncil.org.au/heatwaves-report

Steinfort, U., A. Contreras, F. Albornoz, S. Reyes-Paecke, and P. Guilleminot. (2020). Vegetation survival and condition in public green spaces after their establishment: Evidence from a semi-arid metropolis. *International Journal of Agriculture and Natural Resources*, *47*(2), 90–104.

Stratópoulos, M., C. Zhang, K.-H. Häberle, S. Paulet, S. Duthweiler, H. Pretzsch, and T. Rötzer. (2019). Effects of drought on the phenology, growth, and morphological development of three urban tree species and cultivars. *Sustainability*, *11*(18), 5117.

Strohbach, M.W., E. Arnold, and D. Haase. (2012). The carbon footprint of urban green space: A life cycle approach. *Landscape and Urban Planning*, *104*(2), 220–229.

Tang, Y., A. Chen, and S. Zhao. (2016). Carbon storage and sequestration of urban street trees in Beijing, China. *Frontiers in Ecology and Evolution*, 4, 53.

TNC and RM. (2019). Living Melbourne: Our metropolitan urban forest, accessed 3 March 2021 at https://resilientmelbourne.com.au/living-melbourne/

United Nations. (2018). The world's cities in 2018: Data booklet, at www.un.org/en/events/citiesday/assets/pdf/the_worlds_cities_in_2018_data_booklet.pdf

Vásquez, A., C. Devoto, E. Giannotti, and P. Velásquez (2016). Green infrastructure systems facing fragmented cities in Latin America: Case of Santiago, Chile. *Procedia Engineering*, *161*, 1410–1416.

Vásquez, A., M. Lukas, M. Salgado, and J. Mayorga. (2017). Urban environmental (in) justice in Latin America, in R. Holifield, J. Chakraborty, and G. Walker (eds), *The Routledge Handbook of Environmental Justice*. London: Routledge, pp. 556–566.

VEAC. (2011). Metropolitan Melbourne investigation: Final report, accessed 3 March 2021 at www.veac.vic.gov.au/documents/VEAC152-MMI-Final-Report-FINAL-low-res.pdf

Wang, J., C. Hu, B. Ma, and X. Mu. (2020). Rapid urbanization impact on the hydrological processes in Zhengzhou, China. *Water*, *12*(7), 1870.

Ward Thompson, C., P. Aspinall, J. Roe, L. Robertson, and D. Miller. (2016). Mitigating stress and supporting health in deprived urban communities: The importance of green space and the social environment. *International Journal of Environmental Research and Public Health*, *13*(4), 440.

World Population Review. (2021). Jakarta population 2012, accessed 26 February 2021 at https://worldpopulationreview.com/world-cities/jakarta-population

Ziter, C. (2016). The biodiversity–ecosystem service relationship in urban areas: A quantitative review. *Oikos*, *125*(6), 761–768.

Zölch, T., J. Maderspacher, C. Wamsler, and S. Pauleit. (2016). Using green infrastructure for urban climate-proofing: An evaluation of heat mitigation measures at the micro-scale. *Urban Forestry & Urban Greening*, *20*, 305–316.