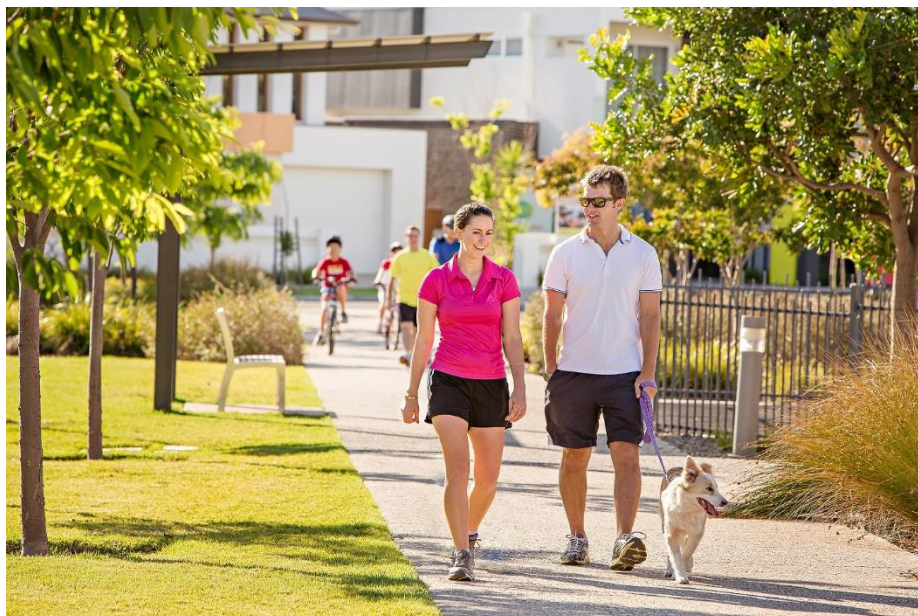# Quality Green Space Supporting Health, Wellbeing and Biodiversity:
A Literature Review

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Executive Summary

Design and delivery of open spaces that promote the health and wellbeing of people and the natural environment is a key challenge for health and urban planning in rapidly growing cities. There is growing recognition of the need for higher-density more compact urban form to accommodate the growing urban populations. In turn, this places greater pressure on Public Open Space (POS) and green spaces within urbanised areas and emphasises the important role of city planning to incorporate green spaces. A greater understanding of how these spaces should be designed is needed to support human health and the environment, including the physical, mental and social health of individuals and communities, and the maintenance of ecosystem services and biodiversity.

This review has been prepared for a collaborative project between the Heart Foundation (South Australian Division), the South Australian Local Government Association, the South Australian Government Departments of Health and Ageing, Office for Recreation and Sport, and the Department of Environment, Water and Natural Resources. The literature reviews evidence on characteristics of POS and green space that benefits human health and wellbeing, biodiversity and ecosystem services. The review summarises findings from an emerging research field, which considers the relationships and benefits between POS and green space characteristics, and physical, mental and social wellbeing, biodiversity and ecosystem services.

In this review, we have attempted to define the key constructs of POS and green space, which are not well articulated in the literature. Terminology and definitions are provided early in the review, before a summary of key findings in the literature describing evidence of urban density influences green space, and the benefits of green space for physical health, mental health and wellbeing, ecosystem services and biodiversity. The report concludes with a Green Space Matrix summarising relevant green space characteristics and their associated benefits derived from the evidence, recommended principles to achieve co-benefits and a model of geographic scale for consideration in green space design and delivery.

A number of key findings derived from the evidence are provided below:

- There is a lack of consensus and clarity in the literature about a clear separation between definitions of POS and green space. This report therefore differentiates between the more general term of POS and publicly available and private green space.
- Green space includes both public and private areas which has implications on composition, distribution and structure of green space and their associated management practices.

- Green space and POS targets are identified within the recently released United Nations Sustainable Development Goals and meeting these goals will be particularly important and challenging with increasing urbanisation and densification within cities.

- Public health research is dominated by attempts to understand the health benefits of access to open space and how this can be expressed in land use planning, while environmental research is focused on the benefits of patterns in land cover such as vegetation type irrespective of land use and tenure.

- Numerous health benefits are associated with access to POS but the evidence is inconclusive on the exact amount of POS required to meet the needs of higher density communities.

- Provision of POS has health benefits including obesity reduction, lowered blood pressure, extended life span and provides important places to engage in physical activity while evidence is inconclusive if proximity to POS initiates or maintains physical activity levels.

- Exposure to nature experiences in hospitals is associated with faster surgical recovery, patient healing and higher pain thresholds.

- Exposure to green space has positive impacts on mental health, particularly through stress reduction and attention restoration.

- Access to green space has been associated with child development through play and motor skill development, improved concentration, wellbeing and increased physical activity. The presence of neighbourhood sports ovals and parks is associated with moderate-vigorous physical activity in young people.

- The presence of neighbourhood green space, streetscape vegetation, landscaping, paths and amenities promotes social interaction and is associated with an increase in perceived community and social cohesion. Dog walking is also an important influence on increased physical activity and social interaction, but can lead to conflict with other park users.

- Trees, vegetation and green surfaces (roofs, facades) are an important source of cooling within cities, helping mitigate the urban heat island effect and climate change. Green areas can reduce temperatures by 1-4 °C decreasing with distance from green space and the size of this cooling effect is influenced by surface area, vegetation type and spatial configuration.

- Hydrological processes are dramatically altered by the presence of impervious surfaces such as roads and buildings. Green spaces and green surfaces slow and filter the runoff from rain events, which helps improve water quality, and reduce storm water runoff, flooding, and waterway pollutants. These changes improve urban habitats and help maintain biodiversity in cities.

- Traditional European plant selection in green spaces in south-eastern Australia has led to decreases in the biodiversity of native bee species and increasing abundance of generalist European Honeybees which are more common in residential landscapes. The management and selection of plant species in green spaces has long-term implications on the pollination of urban remnant vegetation and on urban food production.

- Carbon sequestration is maximised in green spaces with large trees which can store large amounts of carbon but limited in green spaces dominated by shrubs, lawns and flower beds.

- Green spaces can provide natural noise buffering: vegetation belts of between 1.5-3m can significantly reduce perceived and actual noise through direct (e.g. absorption) and indirect (e.g. reduced wind) effects as well as enhancing the pleasantness of an urban environment. Wider belts with large trees are needed to attenuate low-frequency noise such as traffic rumble.

- Vegetated areas can help purify the air by filtering atmospheric pollutants include nitrogen dioxide and sulphur dioxide, and larger particulate matter (e.g. PM10). There is some evidence to suggest that trees can have negative effects on air pollution by trapping pollutants in 'street canyons' lined with tall buildings and some trees emit biogenic volatile organic compounds, which are themselves pollutants.

- Green spaces can help maintain and enhance soil quality and function. Building and road construction can reduce soil pH and degrade native soils through removal, compaction or burial. Soils in green spaces provide important hydrological (e.g. filtering and slowing stormwater) and biogeochemical functions (e.g. decomposition) that are diminished under paved areas.

- Green spaces are associated with increased biodiversity, particularly for plants, birds, arthropods and amphibians.

- Habitat structure is of central importance to animal biodiversity driven by the complexity and diversity of the understorey and canopy vegetation, leaf litter, logs, long grass, as well as wetlands, streams, garden ponds, ornamental lakes, ponds and drains.

- The composition of plant species in green spaces is also an important determinant of biodiversity, including insect and animal richness and abundance. Both native and exotic plants contribute to biodiversity and the use of native plants can promote some kinds of biodiversity such as endemic plant and animal species.

- Threatened species are present in many different locations in Australian cities and management practices of green spaces where they occur need to be devised based on their influence and contribution to national biodiversity conservation and species recovery planning. At least 132 native species of plants and animal have become locally extinct in the Adelaide region to date.

- Several ecosystem 'disservices' - or negative consequences of green spaces have been identified in the literature ranging from tree root damage to footpaths, allergies from pollen, to falling tree limbs. These disservices can be avoided or mitigated through careful design, management and community education.

- The benefits of green spaces are also shaped by broader contextual factors including the physical environment, climate, intensity of urbanisation, population density and social and demographic factors such as gender, age, ethnicity and socioeconomic status. Sustainable levels of tree canopy cover and ''greenness" vary with location, climate and time of year.

- Green space is particularly beneficial for people living in socioeconomically disadvantaged areas. Green space and green cover have been found to be inequitably distributed across Australian cities and Adelaide has the least equitable distribution of all capital cities with 20% of land covered by green space in the most affluent areas compared to 12% in least affluent areas.

- Further research is needed to identify the economic benefits of green space according to comprehensive measures of physical health, mental health, ecosystem services and biodiversity.

- The evidence from this review suggests that developing a strategy to enhance public open green space across Adelaide, particularly in areas with high or increasing housing density, will promote health, produce essential ecosystem service benefits, protect the environment and enhance biodiversity.

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List of Abbreviations

LGA   Local Government Area

NDVI   Normalised Differentiation Vegetation Index

POS   Public Open Space

UHI   Urban Heat Island

1. Introduction

Adelaide's population is continuing to grow and become more compact. As we shift towards these denser urban environments, the city and suburbs will lose private green space and become more reliant on green space in the public realm, including parks, streetscapes, land and water corridors. This literature review considers the multiple benefits of green space and identifies key considerations for best practice planning to maintain urban liveability and the health and wellbeing of residents.

This review is particularly important as the goals and objectives of the *Planning Reform* and the updated *30-Year Plan for Greater Adelaide* begin to be realised, and the delivery of higher-density housing becomes more common. Well-designed, dense urban environments designed to encourage active travel can increase health and wellbeing (Giles-Corti, Ryan et al. 2012). However, the integration of planning, design, construction and management of *quality* open space into urban planning processes is challenging, and will become an increasingly important consideration in promoting physical and mental health (Hartig and Kahn 2016), urban liveability (Badland, Whitzman et al. 2014) and active lifestyles (Paquet, Orschulok et al. 2013), particularly given the projected loss of private open space in communities. Dense urban landscapes are also challenging for urban biodiversity and providing ecosystem services; challenges that can be addressed through careful design that recognises the interrelated effects of urban landscaping decisions. Hence, a key factor explored in this evidence review is what constitutes 'quality' open space that meets the wide spectrum of needs for mental and physical health, wellbeing, biodiversity and ecosystem services.

2. Defining Public Open Space and Green Space

Varying definitions of Public Open Space (POS) are used across all levels of government and academic literature (Koohsari, Mavoa et al. 2015) and multiple definitions, spatial units and data sets have been found to influence area-based POS calculations (Daker, Pieters et al. 2016, Taylor and Hochuli 2017). One of the greatest complexities is the lack of consensus on the separation between POS and green space, or the use of clearly defined constructs in the literature (Taylor and Hochuli 2017). There is considerable overlap between the two constructs as described in Figure 1.
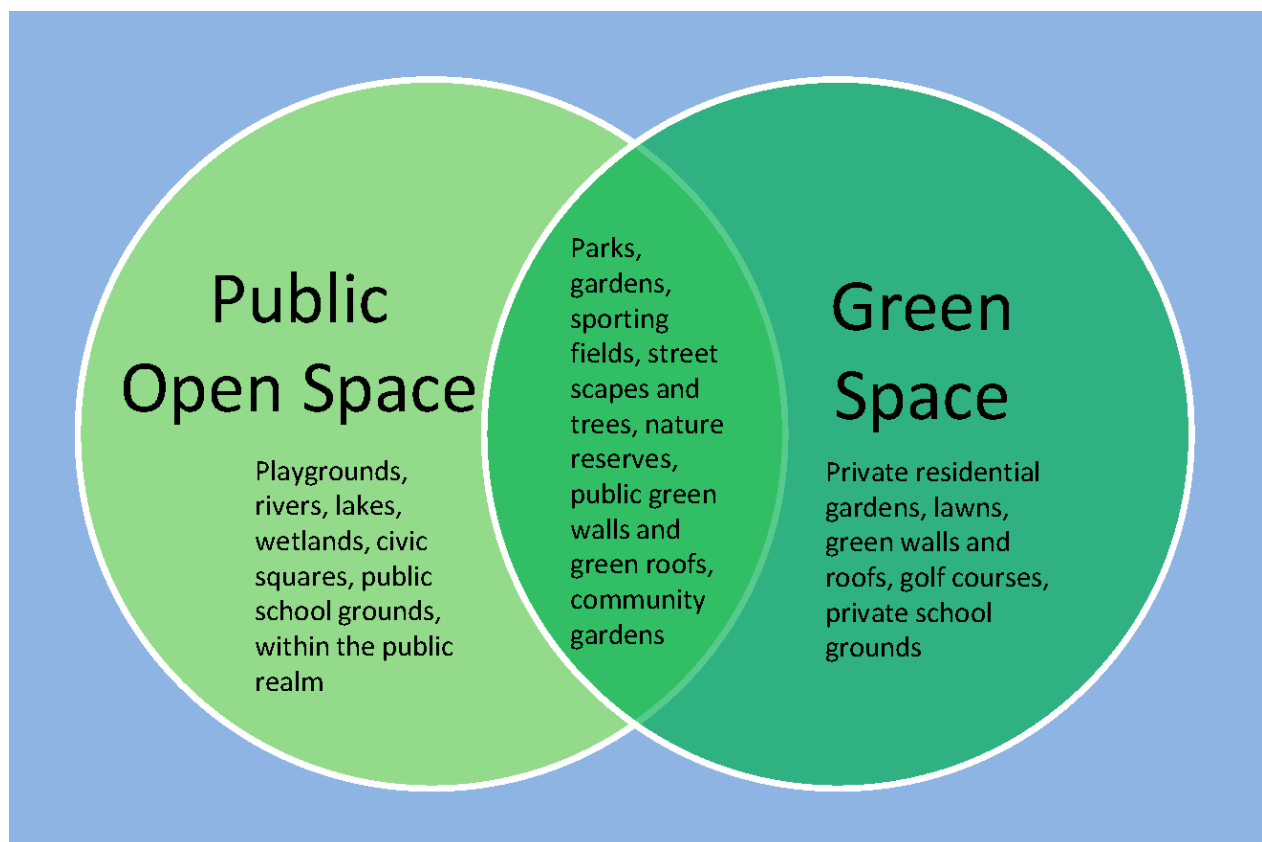
Figure 1: The overlapping constructs of Public Open Space and Green Space.

POS describes vegetated and non-vegetated land freely available to the public within the urban landscape. Vegetated areas include parks, many streetscapes, public gardens, playgrounds, sporting grounds, rivers, lakes, wetlands, conservation areas, some civic squares, community and some rooftop gardens in the public realm (Alexander 1977, Villanueva, Badland et al. 2015, Daker, Pieters et al. 2016). The variety of spaces included within POS means that it often includes both a mixture of hard (i.e. impervious) and soft (permeable) landscape surfaces.

Green space is a broader but overlapping concept to POS because it is not solely dependent on public access or public management and is defined as both public and private spaces with predominantly soft permeable surfaces such as soil, grass, shrubs and trees (Dunnett, Swanwick et al. 2002). Green space includes all public and private urban vegetated areas including parks, sporting grounds, private gardens, treed streetscapes, remnant native vegetation, golf courses, green roofs, and green walls (Norton, Coutts et al. 2015).

Much public health research and practice has focused on POS according to how land is used in relation to health benefits (e.g. open space for active or passive recreation or conservation). This is quite different to environmental research and practice where there has been a greater emphasis on land cover (e.g. built areas vs native vegetation vs trees vs turf) (Tzoulas, Korpela et al. 2007) with less consideration of human interactions with green space and community recreational needs. Consequently, public health research has generally focused on how *land use* zoned for POS influences public health outcomes while environmental research has focused on how *land cover* influences environmental outcomes. Some public health definitions of POS combine land use and land cover, albeit with a greater emphasis on land use. For example, the Western Australian POS tool (Broomhall, Giles-Corti et al. 2004) categorises POS as: parks with grassed areas catering for active and passive recreation; natural environments designed for conservation and biodiversity; school grounds and sports surfaces; and residual green spaces with poor function and location[1]. However, as our urban areas densify and the importance of POS increases, there is growing interest and importance in developing a greater understanding of how both land use and land cover influences health, wellbeing and ecosystem services such as cooling and biodiversity.

An example highlighting the differences between land cover and land use is provided in Figure 2. The left map in Figure 2(a) is a POS map for a selected area revealing all the POS areas defined according to land type usage. The right map in Figure 2(b) is a Normalised Differentiation Vegetation Index (NDVI) measuring live vegetation types across both public and private spaces including residential housing. The example is a clear illustration on how a *land use* versus a *land cover* definition of urban areas produces very different results, and highlights the importance of both public and private impact on vegetation coverage.

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[1] www.postool.com.au

2(a) POS defined according to land use mix.	2(b) NDVI vegetation cover of the same area.
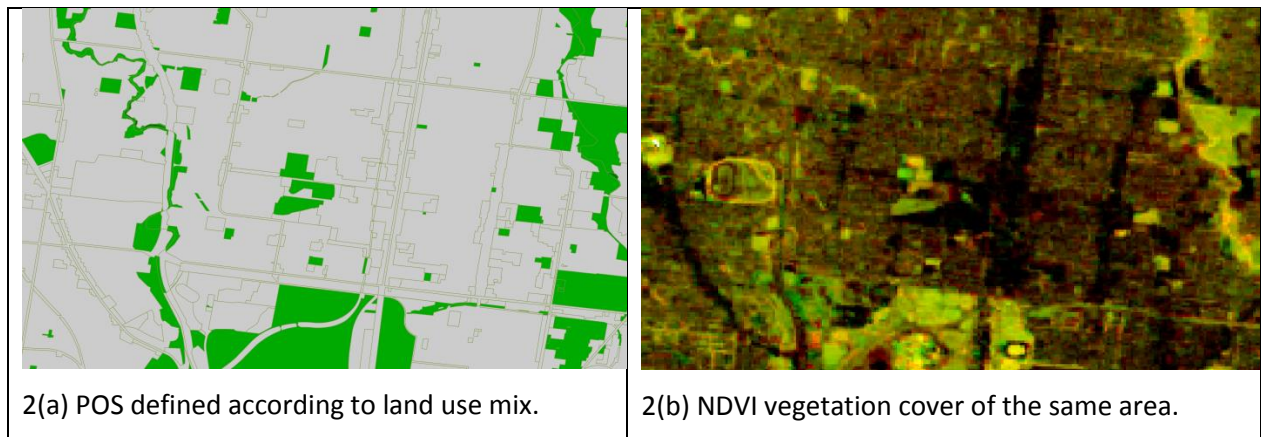
Figure 2: A comparison of Public Open Space (POS) defined by land use mix (2a) versus land vegetation coverage using Normalised Differential Vegetation Index (NDVI) (2b).

For the purpose of this report green space is defined as a broader concept that incorporates POS as identified in Figure 1 and includes vegetated areas on both public and private land. Urban green space describes all the vegetated areas that occur in cities including parks, conservation reserves, residential gardens, and street trees (Kabisch and Haase 2013).

An important characteristic of urban green space is its tenure: it can be either on public or private land. Green spaces on public land include POS such as formal parks and recreation reserves while green space on private land includes residential gardens and lawns in front and backyards. Both private and public green spaces have important roles in the health, wellbeing and biodiversity of our suburbs. Urban green space is widely considered essential social and environmental infrastructure for a sustainable city, and provides the fabric of cities as social-ecological systems. Urban green space supports a broad spectrum of activities and interactions between people and nature and is considered critical to sustain environmental function for the health of communities (Villanueva, Badland et al. 2015).

Green space or green infrastructure networks consist of a combination of public spaces freely available to all (e.g. streetscapes, remnant nature reserves, public parks) and private spaces (e.g. golf courses and residential gardens) (Tzoulas, Korpela et al. 2007) and can cover a large proportion of Australian cities. For example, 41% of houses in Australian capital cities have a publicly accessible street tree and 77% have a tree in their residential garden (Kirkpatrick, Daniels et al. 2011). A study of the regional city of Ballarat in Victoria found that 13% of the city was zoned as recreational or conservation parks, 28% of the city was covered in trees and a further 24% of the city covered in lawn (Kendal, Williams et al. 2012). The interest in POS and green space is of interest to broad levels of government and topical for state government planning bodies.

For example, the Victorian Planning Authority has recently released a comprehensive online spatial dataset of the open space network for metropolitan Melbourne to assist with maintenance and future planning.[2] Moreover, Melbourne Water, is looking to increase access to 33,000 hectares of green space under its ownership across Melbourne to enhance Melbourne's liveability.

The management of both public and private urban spaces presents its own challenges. Different types of public and private green space are subject to various formal and informal management practices depending upon the ownership, objectives, available resources (including time and money) and current understandings of best-practice management (Threlfall, Walker et al. 2015). Furthermore, differences in ownership and custodianship contributes to a diversity of green space management practices which influence the structure, composition, and distribution of green spaces across the urban landscape. Management decisions are influenced by planning guidelines, conservation obligations, homeowners associations, individual park management contractors, local friends groups and the social norms and values of residential home and garden owners (Kendal, Williams et al. 2012).

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[2] https://vpa.vic.gov.au/strategy-guidelines/metropolitan-open-space-network/

3. The importance of Public Open Space and green space in cities

Worldwide, the percentage of people living in urban areas will increase from 50% in 2010 to nearly 70% by 2050 (United Nations, 2015). Australia is no exception to this trend. In 2012, 66% of Australians lived in a capital city and by 2061 this proportion is projected to increase to 74%. South Australia's population is projected to increase by 39%, to 2.3 million people by 2061, with Adelaide's population projected to increase from 1.3 million in 2012 to between 1.7 and 2.2 million in 2061 (Australian Bureau of Statistics 2013).

Why are Public Open Space and Green Space important?

POS and green space are considered important for public health, personal wellbeing and vital for the provision of urban ecosystems services and maintaining biodiversity in cities (Swanwick, Dunnett et al. 2003). These spaces are widely understood as 'improving' cities by increasing amenity and providing places for both passive and active recreation. The early design of 19th century park provision reflected democratic values in urban design where all members of civil society interacted while current urban design generally attempts to distribute POS equitably to meet the needs and desires of diverse urban communities (Thompson, Roe et al. 2012). Since the 1970s, areas of green space in cities have also been set aside for conservation purposes to protect natural heritage and rare and threatened plants, animals and ecosystems.

Urban green spaces also contribute to the resilience of cities by ameliorating the effects of sudden shocks such as heat waves and storms (Gill, Handley et al. 2007). Urban green spaces contribute significantly to cooling and can reduce temperature extremes by several degrees. The impervious surfaces in urban green space can also slow the runoff of stormwater during storm events, reducing floods and contribute to mitigation and adaption to global environmental change such as urban heat and climate change. For example, increasing tree canopy cover can help to mitigate the effects of climate change by sequestering carbon (Dobbs, Kendal et al. 2014) and adapt to urban heat by increasing the provision of shade and cooling in cities (Gill, Handley et al. 2007). The benefits of green space for people and biodiversity are discussed further in Section 5 of this report.

How do these benefits relate to the Sustainable Development Goals?

The importance of green space in developing populous nations like Australia is recognised on a global scale through the United Nations 2030 Agenda for Sustainable Development. The Agenda is built around the 17 Sustainable Development Goals (SDG's) (Figure 3) for the next 15 years. The SDG's include a city-specific Goal 11 to 'Make cities inclusive, safe, resilient and sustainable'.

One of the targets for this goal is directly related to the provision of urban green space: 'By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities' (United Nations, 2016). The benefits provided by green spaces also indirectly contribute to other Sustainable Development Goals such as Goal 3, 'Ensuring healthy lives and promote well-being for all at all ages', Goal 13 "Take urgent action to combat climate change and its impacts' and Goal 15 'Sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss'. The provision and management of green space will make an important contribution to Australia's ability to meet the Sustainable Development Goals. The role of green space for public health and wellbeing is also an important component of the New Urban Agenda, a global agenda for the sustainable development of cities recently agreed to at HABITAT III in Quito, October 2016.

Figure 3: The 17 United Nations Sustainable Development Goals 2015-2030 (www.un.org/sustainabledevelopment/sustainable-development-goals).

With rapid urbanisation globally, the need for sustainable urban development is increasingly important (Haaland and van den Bosch 2015). Compact or dense city forms are being promoted as alternative city forms to accommodate growing populations and counteract some of the negative effects of urban expansion and urban sprawl. The 'compact city' is characterised by high density housing, well-functioning public transport and promotion of cycling and walking (Burton 2000). While

there are many positive aspects to city densification (e.g. localised services and increased walking), there can be negative effects (e.g. crowding and increased traffic congestion) when densification is not carefully managed. Many of the positive outcomes thought possible by developing higher density cities are being questioned, such as reduced traffic and environmental problems (Neuman 2005, Howley 2009). Consequently, it is timely in Australia to consider how to optimise the health benefits of higher density development and minimise any harms (Giles-Corti, Ryan et al. 2012).

One important issue in compact city development is concern about the lack of urban green space in dense urban areas and the removal of green space when densifying city areas (Fuller and Gaston 2009, Brunner and Cozens 2013). For example, the transformation of open space is evident within established suburbs of Adelaide where many of the older suburbs of Adelaide were designed with more private open space and less POS. Over time, with infill development, these older suburbs have experienced a significant loss of private open space without a corresponding increase in POS (Sivam, Karuppannan et al. 2012). This has led to a substantial decrease in access to the overall percentage of green space in these residential areas. In contrast, newer suburbs of Adelaide have been designed and developed with more POS and less private open space. Planning and management of overall levels of urban green space is therefore a crucial issue in the context of increasingly compact cities, and needs to ensure that these spaces meet the health and wellbeing needs of urban dwellers while also offering crucial biodiversity and ecosystem services (Goddard, Dougill et al. 2010).

4. Increasing urban density influences the need for green space

Given the health benefits associated with access to POS, it is important to consider how much green space is required to meet the health and wellbeing needs of rapidly growing populations living in more dense environments. This is a challenging question, with no clear guidance from the literature, and different states and cities using different approaches to estimate community need, with little evaluation to suggest what might be the optimal amount of POS required to protect health and wellbeing. A 2012 report prepared for the Heart Foundation (Giles-Corti, Ryan et al. 2012) attempted to estimate the amount of POS required using a standard approach reflecting the number of people it was designed to serve - i.e. the levels of population density (see Table 1). Using a traditional 'standards' approach, it showed that the amount of POS required significantly increases as the population served by that POS rises. At a density of 35 dwellings per hectare, this approach suggests that 32% of land area should be allocated to POS; while 56% of land area would be required for densities of 60 dwellings/hectare.

Table 1: Standards for the average amount of public open space required in housing developments with different levels of density adopted from guidelines proposed by Stephenson and Hepburn (1955) (modified from Giles-Corti, Ryan & Foster, 2012).

A	B	C	D	E	F
Number of dwelling per hectare	Average number of residents/ hectare i.e., Column A x 2.6	How many hectares/60,000 persons i.e., a District? i.e., 60,000/Column B	How many acres/60,000 persons i.e., a District? (i.e., Column C x 2.47)	How many acres of POS required for 60,000 people i.e., a District? i.e., Amount of POS * 60	% green space required for housing development for 60,000 people at different levels of density i.e., Column E/ Column F
1	3				
12	31	1923	4750	498[1]	10
35	91	659	1629	528[2]	32
50	130	462	1140	528	46
60	156	385	950	528	56

[1]8.3 acres/1000 persons excluding green space in schools (i.e., 1.9 acres/1,000 persons). [2]8.8 acres/1000 persons excluding green space in schools (i.e., 1.9 acres/1,000 persons) but adding 0.5 acres/1,000 for the local 'green' omitted from the Stephenson and Hepburn report on the basis that people have their own back-yards.

Nevertheless, despite this modelling, this report was inconclusive on the exact amount of POS required to meet the needs of higher density communities recognising the need to be both practical, and to meet the needs of rapidly growing urban populations. However, unquestionably, it concluded that '…given the physical, mental, social and environmental benefits of public open space for communities, and the potential for more people to rely on public open space for recreational needs and restorative benefits as density increases and private open space declines, … more land will need to be allocated to public open space in higher density than suburban areas'.   Moreover, in addition to simply focusing on the amount of POS, careful thought needs to be given to the design and types of POS provided, to meet the needs of multiple users across the life course, while at the same time maintaining biodiversity given loss of green space generally across cities.

Existing evidence supports neighbourhood development that encourages walking and associated health outcomes. Future urban design of our cities should be based on higher density, distance to public transport, destination accessibility, diversity, design, demand management (parking policies) and placemaking (Udell, Daley et al. 2014). Density matters and so does the walkable quality of the street environment which requires destinations and attractive spaces that encourage people to spend time in their streets and local communities. Density needs to be appropriate, in the right location, appropriate height, good land use mix and good design for it to create good compact attractive walkable urban neighbourhoods (Udell, Daley et al. 2014). Green space will play an increasing important role in the future design of these locations and support the physical, mental and social health of communities as well as biodiversity and ecosystem services. Furthermore, future urban design incorporating urban greening should extend beyond POS and park based infrastructure and also consider additional greening solutions such as green roofs, walls, facades and increased greening in streetscapes.

5. Benefits of Public Open Space

To balance the needs of people and biodiversity in cities, local governments are increasingly incorporating green spaces and urban greening initiatives into urban planning frameworks. Green space can provide a range of benefits to urban residents including social benefits (e.g. promoting physical and mental health), ecosystem service benefits (e.g. cooling, pollination, noise reduction) and provide critical support for urban biodiversity (e.g. providing habitat and foraging opportunities to a range of birds, animals, insects as well as supporting native vegetation communities). These benefits of green POS in urban areas are further summarised below.

Benefits of Public Open Space to people's physical health

A growing body of literature has assessed the physical human health benefits of POS in urban areas. The majority of these studies indicate that there is, in general, a positive relationship between greener environments, contact with nature, and physical health.

Physical activity

The provision of attractive, open green spaces, such as parks, or recreational spaces, such as sports ovals, provide important places for people to engage in physical activity (Giles-Corti, Broomhall et al. 2005, Lee and Maheswaran 2011, Astell-Burt, Feng et al. 2014, Wolf and Robbins 2015). Physical activity in or near green space has been linked to important health outcomes including obesity reduction, lower blood pressure and extended life spans (Astell-Burt, Mitchell et al. 2014, Wolf and Robbins 2015). 'Green exercise', defined as physical activity undertaken in green or natural environments (Barton and Pretty 2010), is also thought to be more beneficial than other types of exercise (Marselle, Irvine et al. 2013). For example, running in a park is associated with a more restorative experience compared with the same exercise in an urban environment (Bodin and Hartig 2003). Studies have also shown that residents living in neighbourhoods with more urban green space were more likely to participate in leisure-time physical activity than those living in areas with less urban green space (McMorris, Villeneuve et al. 2015). The provision of POS to facilitate physical activity is particularly important for children, adolescents, and the elderly (Bell, Wilson et al. 2008, Sugiyama, Thompson et al. 2009). Nevertheless, there are complexities; for example, a South Australian study by Sugiyama and colleagues (2013) concluded that while the presence and proximity of POS may not assist adults to initiate walking, it might influence the maintenance of recreational walking over time. This suggests that additional behavioural strategies might be required to increase the use of green space in order to maximise the physical health benefits of its availability.

When neighbourhood parks are used for recreation, health or fitness, the presence of four attributes (grassed areas, amenities, dog-related facilities, and off-leash areas for dogs) have been found to be important attractors to POS regardless of size and when POS attributes were weighted for size, the presence of gardens, water features and wildlife were associated with walking (Sugiyama, Gunn et al. 2015). Findings suggested that larger and better quality POS was most likely to support recreational walking and optimal for physical activity in preference to small POS with fewer amenities and of poorer quality.

Obesity

Access to green space is one potential indirect environmental determinant of obesity with several studies finding higher levels of neighbourhood green POS to be associated with lower levels of obesity (Bell, Wilson et al. 2008). Similarly, Pereira and colleagues (2013) found that higher levels and greater variation in neighbourhood greenness were associated with lower odds of obesity among adults of all ages. The pathway through which green POS impacts obesity is thought to be through encouraging physical activity. As noted above, access to green POS has been shown to be associated with physical activity, and through this pathway, is thought to contribute to reducing the occurrence of obesity and improving health (Lachowycz and Jones 2011).

Morbidity

Some studies have found associations between morbidity and accessibility and quantity of neighbourhood green space (Maas, Verheij et al. 2009). For example, studies have found associations between low quantities of neighbourhood green space and elevated risk of circulatory disease (Mitchell and Popham 2008). Furthermore, although not all pathways are articulated, there is evidence that access to and use of green POS appears protective of several diseases including chronic heart disease, respiratory tract infection, asthma, migraine and severe headaches, vertigo, acute urinary tract infection and diabetes mellitus (Maas, Verheij et al. 2009, Astell-Burt, Mitchell et al. 2014). Pereira and colleagues found that variability in neighbourhood greenness was negatively associated with hospital admissions to coronary heart disease and stroke (Pereira, Christian et al. 2013) and larger, greener and more active POS associated with lower risk of cardiometabolic disease but with the number or proportion of POS in the residential environment (Paquet, Orschulok et al. 2013). Once again, it is likely that the pathway is through impacts of physical activity, as the prevalence of some of these diseases has been found to be significantly lower in individuals who are regular green POS users (Tamosiunas, Grazuleviciene et al. 2014).

Physical healing and pain

Several studies have demonstrated that access to natural landscapes, through nature experiences or even views of nature, can assist physical healing (e.g. faster surgical recovery and patient healing) and are associated with higher pain thresholds in hospitals (Wolf and Robbins 2015). A seminal research study conducted by Ulrich (1984) found that hospital patients in rooms with a view of a green setting recovered faster from surgery than patients with a view of a brick wall. This may be due to nature serving as a distraction resulting in increased pain tolerance and improved coping (Ulrich 1999), or that exposure to nature reduces stress levels (Kaplan 1983), with higher levels of stress associated with negative health outcomes (Varni and Katz 1997).

Benefits of green space for mental health and wellbeing

It is generally agreed that long term exposure to urban stressors such as noise, crowding and fear of crime without possibilities for restoration from stress, can affect mental health and increase the risk of depression, anxiety and fatigue syndromes (Marin, Lord et al. 2011). There is consensus that living environments with green spaces, such as urban parks, forests and nature areas, are important restorative environments for urban dwellers (van den Berg, van Poppel et al. 2016).

Stress reduction & relaxation

Stress response is associated with sleep loss, supressed immune system, stroke, diabetes, high blood pressure, cardiovascular disease (Wolf and Robbins 2015). Several studies have shown that stress reduction and relaxation are associated with exposure to green views (Kahn, Friedman et al. 2008) and spending time or exercising in green areas (Bodin and Hartig 2003, Wolf and Robbins 2015). There is convincing evidence from several studies that access to natural environments can help individuals to recover from acute stress and mental fatigue better than other environments (Bodin and Hartig 2003, van den Berg, van Poppel et al. 2016). Frequent visits to green spaces have also been associated with lower levels of perceived stress and cortisol levels (Grahn and Stigsdotter 2010, Thompson, Roe et al. 2012) and people living in greener neighbourhoods tend to report less stress, and have lower cortisol levels (Roe, Thompson et al. 2013). However, studies have found only short-term restorative benefits of an episode of experiencing nature (Hartig, Evans et al. 2003, Fuller, Irvine et al. 2007).

General mental health

Contact with nature is widely considered important for general mental health (Wolf and Robbins 2015). Recent studies have demonstrated being in green spaces reduces frustration and distress (White, Alcock et al. 2013) and urban dwellers who perceived their neighbourhood to be greener were found to have better mental health than those who perceived their neighbourhood as less green (Sugiyama, Leslie et al. 2008). Residents of neighbourhoods with a high-quality green space had lower

levels of psychosocial distress than those of neighbourhoods with a low-quality open space (Francis, Giles-Corti et al. 2012, White, Alcock et al. 2013). Studies have also found reduced depression in the elderly after walking in gardens (McCaffrey, Hanson et al. 2010) and improvements in mood for people with depressive disorders associated with walking in nature (Berman, Kross et al. 2012).

Mental function and concentration

Studies have demonstrated task attention and focus can be improved by exposure to nature (Kaplan 1995, Wolf and Robbins 2015). Nature experiences in the workplace (e.g. exposure to plants) has been shown to improve employee morale, increase efficiency, boost workplace satisfaction and decrease absenteeism and self-reported sick leave (Kaplan 1993, Fjeld, Veiersted et al. 1998, Wolf and Robbins 2015). Conversely, in office workers, not having nature views or indoor plants has been shown to be associated with higher levels of tension and anxiety (Chang and Chen 2005).

Reduced aggression, violence and crime

Research has also demonstrated that increased access to green space may be linked to reductions in neighbourhood crime, violence, and aggression (Kuo and Sullivan 2001, Branas, Cheney et al. 2011, Garvin, Cannuscio et al. 2013). Recent studies show residents living in "greener" surroundings report lower levels of fear, fewer incivilities, and less aggressive and violent behaviour. Some studies further suggest rates of violence might be reduced by the increased greening of vacant land parcels (Branas, Cheney et al. 2011, Garvin, Cannuscio et al. 2013). Alternatively, some studies have demonstrated perceived fear increases with vegetation in urban areas that could be used for concealment and reduces sight lines (Kuo and Sullivan 2001). Furthermore, POS that has a high level of graffiti and disorder and which is poorly maintained has been shown to increase stress levels in residents and are less likely to be used for recreational walking (Foster, Giles-Corti et al. 2012).

Childhood development

Contact with nature is thought to play a crucial role in the brain development of children (Dadvand, Nieuwenhuijsen et al. 2015). Natural environments including green spaces in cities, provide children with unique opportunities such as risk taking, discovery, creativity, mastery and control, which strengthens sense of self, inspires basic emotional states (e.g. sense of wonder), and enhances psychological restoration which are all thought to influence different aspects of cognitive development (Bowler, Buyung-Ali et al. 2010). A diversity of vegetation and topography within green spaces are believed to contribute to the quality of natural playscapes with these landscape elements also considered important for developing children's motor abilities (Fjørtoft and Sageie 2000).

Repeated and regular contact with outdoor greenness at school has also been associated with improvements in children's confidence, motivation and concentration, language and communication and physical skills (Dadvand, Nieuwenhuijsen et al. 2015). While, exposure to outdoor greenness at home has been associated with improved wellbeing in children (Wells 2000), and particularly for girls, green space immediately outside the home is associated with increased self-discipline (Taylor, Kuo et al. 2002). Research has also shown that when children are engaged in green settings childhood attention deficit disorder symptoms are reduced (Taylor and Kuo 2011, Amoly, Dadvand et al. 2014). There is also some evidence that childhood nature experiences play an important role in developing nature-oriented attitudes and preferences for nature-based activities in adult life (van den Berg, van Poppel et al. 2016).

Another line of research has identified physical inactivity in children as a growing public health concern (WHO, 2016). Regular physical activity in children is associated with numerous benefits, including improved cardio vascular health, reduced risk of type 2 diabetes, and less symptoms of depression and anxiety (Janssen and LeBlanc 2010). Studies have found exposure to green space is associated with higher physical activity in children (Ward, Duncan et al. 2016) and that neighbourhood context is an important factor influencing physical activity in children (Villanueva, Badland et al. 2015). Indeed, the presence of sport ovals and parks has been shown to be associated with moderate-vigorous physical activity in young people, particularly when located within 800 m of their homes (Giles-Corti, Kelty et al. 2009, Villanueva, Badland et al. 2015).

Social interaction and cohesion

There is growing evidence that access to green space enhances social cohesion (Lee and Maheswaran 2011) which is likely to result from enhanced local interactions. For example, presence and ease of access to outdoor green space within neighbourhoods has been associated with an increased sense of community (Kearney 2006, Sugiyama, Leslie et al. 2008, Francis, Giles-Corti et al. 2012) and are considered inclusive spaces that promote social interactions (Peters, Elands et al. 2010). People living near more streetscape vegetation also felt their neighbourhood was more cohesive (De Vries et al., 2013) compared with people living with less neighbourhood green space (excluding street trees and residential gardens) who considered themselves to have less social support and felt more lonely (Maas et al., 2009). A greater sense of community has been linked to views of landscaping and pathways within natural areas, as well as the availability of both less developed natural areas (e.g., native vegetation and lakes) and areas containing amenities (e.g., playgrounds and sports ovals) (Francis, Giles-Corti et al. 2012).

As cities densify, it is also important to accommodate the needs of dog owners. Dog ownership is associated with numerous health benefits, including increased physical activity in owners (Christian, Westgarth et al. 2013, Christian, Trapp et al. 2014) and their children. Dogs, like children, are 'social lubricants' and as people walk their dogs, they get to know their neighbours and other dog owners, with evidence that dog owners tend to have higher levels of social capital than others (Wood, Giles-Corti et al. 2005). Hence, designing green POS to accommodate the needs of dog owners to exercise their dogs in compact cities will be critical to avoid conflicts between park users (Wood, Giles-Corti et al. 2005).

Neighbourhood connection, social capital and a strong sense of community are important because these have all been shown to be associated with improved wellbeing, increased feelings of safety and security, participation in community affairs and civic responsibility. Moreover, access to urban green space has also been linked to positive indicators of functioning societies, such as reduced fear and reduced levels of crime (Kuo and Sullivan 2001).

Benefits of green space for ecosystem services

Ecosystem services commonly refer to the benefits human populations derive, directly or indirectly, from ecosystem functions that maintain or improve human well-being (Costanza, d'Arge et al. 1997). Several studies have identified ecosystem services important for urban areas (Bolund and Hunhammar 1999, Dobbs, Escobedo et al. 2011).

Maintaining a favourable climate

The densification of urban areas is associated with changes in the local climate (e.g. Urban Heat Island). The urban heat island (UHI) effect is caused by paved surfaces that impede evapotranspiration, dense structures that reduce wind speed and dark building materials that absorb solar energy in the daytime and release the heat gradually at night, slowing down the air cooling process. An UHI effect of 7°C has been measured in London (Wilby 2003) and Rotterdam (Klok, Zwart et al. 2012) and can have considerable impacts on urban dwellers including thermal discomfort and increased energy demands for cooling (Yu and Hien 2006).

It is generally agreed that green spaces provide a cooling effect that moderates the UHI, enhances human comfort and reduces energy demand (Armson, Stringer et al. 2012, Derkzen, van Teeffelen et al. 2015). Several studies have identified that vegetated patches have a cooling effect between 1– 4 °C decreasing with distance from the green space (Derkzen, van Teeffelen et al. 2015). The extent of cooling has been measured up to 1 km from the park boundary and the inclusion of water bodies within the green space can provide greater cooling effects (Völker and Kistemann 2013).

The cooling effect is also dependent on the surface area, vegetation type and spatial configuration of the green space (Xie, Wang et al. 2013). In a context of climate change, with the expected increase in temperature, dryness and intensity of heat waves, green areas assume even higher importance as they can create a cooling effect that extends to the surrounding areas (Oliveira, Andrade et al. 2011). Greening interventions, such as tree planting or the creation of parks or green roofs has been proposed as one approach to mitigate the human health consequences of increased temperatures. A number of these interventions are currently being implemented in a number of local government urban forestry strategies in Australian and New Zealand.

Maintaining hydrological processes

Natural hydrological processes have been drastically altered in urban areas by large-scale soil sealing. Effective management of hydrological processes such as stormwater drainage, runoff mitigation, soil water storage and water purification is important for sustainable and resilient cities and towns (Bolund and Hunhammar 1999). In order to maximise beneficial hydrological processes and ecosystem services of urban soils, Ollosa et al (2015) suggest land managers could focus on improving the complexity of habitat patches.

Soils and other habitat components, such as leaf litter and diversity of vegetation layers have significant effects on the hydrology of urban ecosystems by intercepting rainfall, decreasing runoff into stormwater and increasing water infiltration into soils (Nouri, Beecham et al. 2013, Ossola, Hahs et al. 2015). For example, reduction in stormwater runoff can be achieved through planting or conserving existing forested areas and creating other green infrastructure such as green roofs. Trees and soil improve water quality in that they remove harmful substances washed off roads, parking lots and roofs after rain events. Vegetation can also reduce the need for costly stormwater treatment by retaining or slowing the flow of precipitation reaching the ground. These systems reduce the risk of flooding and water treatment costs (Wolf and Robbins 2015). The increased capacity of urban ecosystems to filter pollutants, leachates and sediments, promote evapotranspiration and mitigate the microclimate could provide indirect economical and ecosystem service benefits (Nouri, Beecham et al. 2013). Improving the complexity of urban habitats could also increase their hydrological resilience under climatic change, as well as improving habitat and resources for urban biodiversity (Le Roux, Ikin et al. 2014).

Pollination

If the decline in bee diversity seen in agricultural landscapes (Potts, Biesmeijer et al. 2010) is mirrored in urban landscapes, it could have far reaching consequences for continued reliable pollination of remnant vegetation, horticultural plantings and urban food production, threatening the viability of some plant populations in the urban landscape (Threlfall, Walker et al. 2015). A diversity of bees utilise a range of urban green areas depending on the attributes of the space (e.g. bare soil, tussock grasses, unmanaged and undistributed vegetation, dead or dying vegetation) for nesting and foraging requirements (Threlfall, Walker et al. 2015). Native bee species in metropolitan Melbourne were most absent from residential landscapes and more likely to be found in less intensively managed public parks and golf courses with native vegetation. In comparison, communities of generalist European Honeybees were most likely to be found in suburban gardens that had adapted to exotic flowering plants.

Carbon storage

When quantifying the potential for carbon storage in urban green spaces, two factors are important: the first being volume of biomass, which is proportional to the carbon storage capacity of trees; and the second factor is vegetation type. Almost all above-ground carbon storage takes place in trees and only a small percentage is stored in shrubs and herbaceous vegetation. Where green spaces consist of pruned trees, lawns, and flower beds, little carbon is sequestered and its maintenance can even emit sizeable amounts of CO_2 and nitrous oxide (N_2O) through fertilization practices (Jo and McPherson 1995). Soils however do contain a large carbon stock, particularly the soil beneath lawns (Derkzen, van Teeffelen et al. 2015) and provide an important method for reduction of carbon dioxide in the atmosphere and associated production of greenhouse gas emissions.

Noise reduction

Noise pollution from continuing urbanization, increasing traffic volumes, industrial activities, and a decreasing availability of quiet places in cities is a threat to human health and wellbeing (WHO, 2016). Nuisance from noise is detrimental to neighbourhood liveability, living comfort and work environments and can increase risk of serious health problems such as hearing loss and cardiovascular disease (Bolund and Hunhammar 1999). Green spaces provide noise reduction services by serving as natural sound buffers (Van Renterghem, Botteldooren et al. 2012) with vegetation belts 1.5 – 3m wide thought to significantly reduce noise (Wolf and Robbins 2015). Belts of trees with woody stems can attenuate low frequency noise such as traffic rumble, while shrubs can attenuate high frequency noise.

Vegetation in urban areas provides both a direct environmental noise reduction (e.g. noise by absorption and dispersal) and indirect noise reduction (e.g. noise reduced by lessened wind speeds and the absorptive capacity of soils). Vegetation also increases perceived noise reduction and noise is perceived to be attenuated by vegetation more than it is actually is (Yang, Bao et al. 2011). Studies have found adding the sound of running water such as a fountain reduced the perceived loudness of road traffic noise and bird sounds significantly enhanced perceived pleasantness of the urban soundscape (De Coensel, Vanwetswinkel et al. 2011).

Air quality

In urban areas waste treatment, industry, transport and residential heating installations pollute the air which can lead to increased occurrences of cardiovascular and respiratory disease (Marchant, Leiva et al. 2013). Vegetated areas in cities improve air quality by filtering atmospheric particulates such as nitrogen dioxide (NO_2), particulate matter (PM10) and sulphur dioxide (SO_2) (Nowak, Crane et al. 2006). Furthermore, vegetation takes up more pollutants when pollution concentrations are high (Tallis, Taylor et al. 2011), which supports planting trees and other vegetation near an emission source to benefit citywide average air quality. However, in some situations, trees can trap pollutants in 'street canyons' lined by tall buildings (Vos, Maiheu et al. 2013) and some trees emit biogenic volatile organic compounds (BVOCs) that are themselves a pollutant (Calfapietra, Fares et al. 2013).

Storm protection

Trees and dense vegetation in urban areas are considered important for protection from wind and storm events. Mangroves are also considered important for protecting coastal zones from storms, sea-level rise, floods, and erosion due to their ability to absorb and dissipate wave energy and stabilize coastal land (Gill, Handley et al. 2007).

Maintenance of healthy soils

Urbanisation often results in the alteration of native soil structure, its chemical properties and the diversity of numerous organisms involved in biogeochemical and hydrological processes in soil (Ossola, Hahs et al. 2015). Native soil profiles are most commonly disturbed through removal, compaction or burial (Lorenz and Kandeler 2005, Ossola, Hahs et al. 2015). Studies have found that construction activities reduce pH and increase the sand content in soils under asphalt (Byrne 2007). Several studies have also shown belowground "heat islands" beneath and surrounding asphalt, pavement and gravel (Celestian and Martin 2004, Mueller and Day 2005). Soil temperatures across urbanized ecosystems tend to be characterized by high temporal variability and exhibit fine-scale spatial heterogeneity that reflects spatial patterns of aboveground habitat structure.

The bulk density, nitrogen (N) and organic matter content of urban soils can also be altered by human activities, particularly changes to vegetation structure (Lorenz and Kandeler 2005).

Benefits of green space to biodiversity

While there are extensive and systematic reviews of the benefits of urban green spaces for people's health and wellbeing, there has been relatively little systematic review of the benefits of urban green spaces for non-human organisms. This is largely due to a research focus on the ecology of particular species, which have relatively narrow geographic ranges making cross-city generalisations difficult. Nonetheless, a few patterns have been observed that show some benefits of urban green space for biodiversity and the conservation of native species. There are two ways in which urban greens spaces contribute to biodiversity: 1) the vegetation and structures that make up green spaces can contribute directly to species diversity; and 2) green spaces can provide habitat for other organisms.

Birds

Much of our understanding of the value of urban green spaces for biodiversity has come from studies of urban birds. This is largely because they occur across many habitats, easy to observe and have wide public appeal (Threlfall, Williams et al. 2016). Studies of urban birds have increased our understanding of ways to design and manage urban green spaces to conserve bird assemblages; however it is unclear how these findings are relevant to other taxa.

Many studies suggest that urban bird habitat can improve by retaining large trees (Stagoll, Manning et al. 2010, Stagoll, Lindenmayer et al. 2012), increasing the proportion of native vegetation (Chace and Walsh 2006) and improving habitat complexity or diversity including understorey and over storey canopy vegetation, leaf litter, logs and long grass (Stagoll, Manning et al. 2010).

Arthropods

Understanding how above and belowground food-webs (and linkages between them) are affected by urban habitat structures is needed to inform the design and management of urbanised landscapes in which beneficial predators are conserved and provide the ecosystem service of consuming pests. It has been widely demonstrated that ground-dwelling and soil arthropods in urban areas are strongly influenced by habitat structure (Langellotto and Denno 2004). For example, the activity and abundance of ants across a heterogeneous urbanized landscape is determined by patterns of vegetation structure and microclimate. Furthermore, differences in the structure and composition of leaf litter in urban parks yields differences in species richness and abundance of soil mites and collembolans (Langellotto and Denno 2004).

Earthworm abundances have also been found to decrease in soils covered with gravel and increase in soils covered with bark mulch without plants (Byrne, Bruns et al. 2008).

The distribution and abundance of human disease vectors are also important issues related to arthropods. For example, many studies in urbanized landscapes have reported that local tick abundance and the probability of exposure to many diseases are affected by soil microclimate (especially humidity) which is largely determined by interactions among vegetation, detritus and soil structure (Langellotto and Denno 2004). Despite these early findings there is still much to be learnt about how the design and management of urbanised landscapes impact soil biodiversity.

Amphibians

Amphibians with broad habitat requirements may be able to persist in urban waterbodies including wetlands, streams, garden ponds, ornamental lakes, retention ponds and drains (Hamer and McDonnell 2008). However, these urban waterbodies are often limited in their suitability for amphibians with more specific habitat requirements because many of these locations contain exotic fish, have inappropriate hydrological regimes, receive contaminated runoff and have high human visitation rates or artificial lighting which can disrupt breeding (Hamer and McDonnell 2008). Furthermore, the physical structure of urban ponds may exclude some species, and wetlands surrounded by roads act as a barrier impacting dispersal (Rubbo and Kiesecker 2005).

There are examples of successful reintroductions of amphibians into urban waterbodies through ecological restoration. Factors attributed to successful reintroductions include creation and maintenance of appropriate levels of habitat succession, suitable fluctuations in the hydro period, good water quality, availability of terrestrial habitat, connectivity to surrounding populations and the absence of native or exotic predatory fish (Hamer and McDonnell 2008).

Conservation of native species

Urban green spaces are considered important for the conservation of native species (Aronson, La Sorte et al. 2014). While some species are disadvantaged by urbanisation, urban areas can provide abundant food resources for some kinds of Australian animals. For example, Grey-headed Flying Foxes (*Pteropus poliocephalus*) have become abundant in Melbourne, in part due to the year round availability of food in planted green spaces (Williams et al., 2006). Similarly, some species of insectivorous birds are more abundant in cities due to the increased availability of nectar in green spaces (Shukuroglou and Mccarthy 2006) and urban areas can also provide suitable shelter and nesting habitats for some species (Shukuroglou and Mccarthy 2006).

Studies from the United Kingdom suggest that the identity of plant species (e.g. native vs exotic) in urban green spaces is not an important determinant of some kinds of biodiversity, such as insect species richness and abundance (e.g. Smith et al., 2006). However, a number of Australian studies have drawn clear relationships between the use of native plants in urban green spaces, and the diversity and abundance of Australian animals. In particular, several studies have shown that native bird species benefit from the presence of native plants in streets, parks and gardens (Ikin, Knight et al. 2013).

While some species such as the Peregrine falcon are able to use the built environment as habitat (Chace and Walsh 2006), many species are dependent on green spaces to survive in cities. In one of the few systematic reviews of the effects of green space on biodiversity, Sadler et al. (2010) identified that local habitat structure is very important for many taxonomic groups. As a result of increased availability of some resources and reduced predation, some animal species can become very abundant in urban green spaces and occur at much higher densities than they do outside cities (Williams, McDonnell et al. 2006).

Threatened species

Cities are often located in areas of high biological diversity (Luck 2007), and urbanization is a significant and expanding land-use change that leads to habitat loss and fragmentation (Seto, Güneralp et al. 2012). While the impacts of urbanization on biodiversity are undeniable, this might also make cities especially important for achieving conservation outcomes (Ives, Lentini et al. 2016).

Australian cities are home to different suites of threatened species and support substantially more nationally threatened animal and plant species than all other non-urban areas on a unit-area basis. Ives et al. (2016) highlight and reinforce the global importance of planning and managing urban landscapes to conserve biodiversity. They recommend that practitioners consider the contribution that urban environments could make to national biodiversity conservation and incorporate this information into species recovery planning.

Adelaide falls within the 3 bioregions of Eyre York Block, The Flinders Lofty Block and St. Vincent Gulf. Each of these regions has distinct vegetation type, landform and climate. Since European settlement, the region has lost many of its native flora and fauna species, largely due to land clearing (Tait, Daniels et al. 2005). At least 132 native species of plants and animals have become locally extinct and these unique bioregions of Adelaide have with their own suite of rare of threatened species. A long-term management goal and priority identified for managers is the reintroduction of locally extinct native species, if enough suitable habitats remain (or can be created) and to manage the remaining species and communities (Tait, Daniels et al. 2005).

Influence of artificial night light on biodiversity

There is increasing awareness of the ecological impacts of artificial night light on biodiversity (Hölker, Wolter et al. 2010, Stone, Jones et al. 2012, Kyba and Hölker 2013). Artificial light such as street lighting is known to affect ecological interactions across a range of plant, animal and insect taxa, including behaviours such as foraging, migration, reproduction and communication (Stone, Jones et al. 2012). For example, many insects die of exhaustion congregating around light sources, ultimately reducing population sizes which might affect species further up the food chain (Hölker, Wolter et al. 2010). Migratory fish and birds are known to get disorientated by artificial night lighting resulting in excessive energy loss and altered migration patterns reducing migratory success (Hölker, Wolter et al. 2010). Lighting around bat roosts can delay nightly emergence (Downs, Beaton et al. 2003) which causes bats to miss the peak abundance in insects that occurs at dusk which can significantly reduce foraging opportunities (Stone, Jones et al. 2012). However, some bat species forage actively under street lights, taking advantage of the high densities of insects attracted to light (Eisenbeis, Rich et al. 2006). Other daytime feeding species might extend their activity with extended illumination, therefore increasing predation pressure on nocturnal species. For plants, artificial light at night can cause early blooming, late leaf loss and extended growing periods, which could impact the composition of the floral community (Hölker, Wolter et al. 2010). Few studies have investigated the effects of lighting brightness on biodiversity.

Disservices of green space

The various benefits of green spaces have been identified in this report. However, the disservices that accompany these spaces tend to be overlooked (Lyytimäki et al., 2009). Ecosystem disservices can be thought of as those outcomes of green spaces that can reduce people's health and wellbeing, or negatively affect biodiversity (Dobbs, Escobedo et al. 2011).

Disservices can be generated directly by green spaces (e.g. tree roots breaking pavement), or indirectly as an outcome of management or lack of management e.g. falling tree limbs. Several disservices relevant to urban green spaces have been identified in the literature (Lyytimäki et al., 2008; 2009; Lyytimäki, 2014; Conway & Yip, 2016; Dunn, 2010; Dobbs et al., 2014) including:

- Damage to infrastructure (e.g. tree roots);
- Unwanted shading (e.g. roof solar panels, winter sun);
- Falling leaves creating mess or hazard;
- Falling fruit attracting pests or creating hazards;
- Source/harbour for invasive species;

- Attracting unwanted animals;

- Transmission of zoonotic diseases;

- Allergies from pollen;

- Falling trees and tree limbs;

- Perceived lack of safety (e.g., reducing natural surveillance an issue especially for women);

- Animal noise;

- Animal and plant smells (e.g. algae);

- Animal excrement (particularly bird and dog);

- Poisonous plants and animals;

- Fear and disgust towards wild or semi-wild animals;

- Bushfire;

- Floods;

- Conservation actions (e.g. threatened species protection) restricting human-centred activities e.g. recreation, or reducing landscape amenity.

Some of these disservices may be reduced or avoided with appropriate community education, management and design. However, there is a risk that designing green spaces to avoid disservices will lead to reduced provision of green space elements such as trees. In doing so, this might have negative consequences as the loss of benefits provided by green spaces may far outweigh the prevention of ecosystem disservices.

6. What shapes the benefits provided by green spaces?

The physical environment

A number of studies have identified broader contextual variables that shape the provision of urban green space and the benefits it provides. Physical environmental variables such as climate and degree of urbanisation directly influence the composition, abundance and structure of urban green spaces. These factors also influence the level of benefits provided – for example the provision of cooling is more important in some places at some times of years, but less important in other places and at other times of year.

Climate

Temperature is a very strong driver of the global distribution of plants (Woodward and Williams 1987) and climate has been shown to be a strong predictor of tree species composition in urban green spaces (Kendal, Williams et al. 2012) and a useful predictor of diversity in the urban forest (Kendal, Dobbs et al. 2014). Climate change and increases in urban temperatures due to urban heat are likely to lead to large changes in the composition and structure of urban forests (Kendal & Baumann, 2016).

The benefits provided by urban green spaces are also likely to vary with temperature (Roy, Byrne et al. 2012). Shade trees can significantly reduce energy use in cities with hot summers via a reduction in the use of air conditioners (Akbari, Pomerantz et al. 2001). Similar increases in benefits for human health and wellbeing may flow from the shade provided by trees in hotter cities (Madureira, Nunes et al. 2015). Adelaide has a Mediterranean climate with long dry summers and cool winters with moderate rainfall and is Australia's driest capital city. Due to these climate variables, Adelaide will tend to have different species growing than cities with more uniform rainfall patterns. Selecting species that are well suited to Adelaide's climate is critical to maintaining healthy green spaces, and appropriate management (including irrigation) of green space vegetation is important for the longevity and usability of these spaces. Other climate variables such as rainfall can be locally important in some places. For example, cities with Mediterranean climates with long dry summers tend to have different species growing than cities with more uniform rainfall patterns.

Climate is intrinsically related to maintenance and irrigation to ensure the availability of high quality green space within cities and towns. The Code of Practice of Irrigated Public Open Space Operational Guide (Connelan Consultants and IPOS Consulting, 2015) was developed by a collective of South Australian Government Departments and organisations, and designed to assist local governments, sports clubs and schools with irrigation management of sports grounds.

The Code of Practice includes the example of the City of Marion who developed specific landscape irrigation objectives based on these principles. The local government developed the objectives following the drought period of 2003-2010 which saw much community POS decimated due to inadequate irrigation associated with water restrictions and increased potable water costs during this time. The City of Marion provides an example of a clear Landscape Irrigation Policy based on water sensitive urban design, a framework of irrigation and water management strategies and minimum irrigation necessary for functional requirements of grounds. Importantly, it also makes reference to the Council's Strategic Plan and Healthy Environment Plan.

Level of urbanisation

The level of urbanisation influences the structure and function of urban green spaces (Grimm, Foster et al. 2008). Highly urban areas tend to be warmer than surrounding areas due to urban heat effects. Furthermore, soils tend to be drier as rainfall is captured and piped into stormwater systems rather than allowed to infiltrate through soils, and the chemical composition of the environment varies due to pollution and nutrient deposition. These factors lead to changes in the species composition and structure of urban green spaces.

The social context

The social environment is also an important predictor of the provision of urban green space and the benefits it provides. While many studies have shown that urban green spaces provide health benefits for a variety of people and populations, many studies also show differing health outcomes which are dependent on demographic factors (i.e. gender, age, ethnicity and socioeconomic status) (Maas, Verheij et al. 2009, Dadvand, Nieuwenhuijsen et al. 2015) as well as population density. Furthermore, inequity in the provision and design of green spaces has led these to be less abundant and available in disadvantaged areas (Forsyth, Musacchio et al. 2005). A national study by Astell-Burt and colleagues found that although green space availability was substantively lower in areas with more low income residents, this association varied between cities. Indeed, Adelaide had the least equitable distribution of green space, with approximately 20% greenery in the most affluent areas versus 12% availability in the least affluent areas (Astell-Burt, Feng et al. 2014).

Population Density

Population density is an important limiting factor on the distribution of green cover (Iverson and Cook 2000) and drives the fragmentation of green space (Tian, Jim et al. 2011). High population densities lead to changes in the built form that generally lead to more impervious surfaces, and less impermeable surfaces where plants can grow. These physical limitations may be able to be overcome with a policy focus on increasing both green cover and green space.

For example, between 1986 and 2007, the high density city of Singapore was able to increase green cover from 36% to 47% while increasing population through the implementation of strong greening policy. Limited space on the ground also leads to an increase in green interventions encapsulated within the built environment, such as green roofs and facades (Tian, Jim et al. 2011).

Socioeconomic inequity

As evidence of the health benefits of POS grows, so do concerns over inequities in POS distribution (Astell-Burt, Feng et al. 2014, Mavoa, Koohsari et al. 2014). Socioeconomic status is an important driver of urban greening in public landscapes in Australia and around the world (Iverson and Cook 2000). Some research from the USA suggests that this is the result of a 'luxury effect', where people with the 'economic wherewithal' are able to move to areas with more vegetation, or plant more vegetation themselves (Martin, Warren et al. 2004). However, there is a growing body of evidence showing that this phenomena is being driven by top-down processes where advantaged sections of the community have the capacity to influence the provision of public goods (e.g. street trees) for private gain (Kendal, Williams et al. 2012).

There are potentially large benefits in greening disadvantaged areas. For example, health inequalities have been shown to be smaller in green areas (Mitchell and Popham 2008) and earlier Section 5 provided evidence of increased physical and mental health benefits associated with access to green space. Trees and green space can provide proportionally greater benefits in disadvantaged areas and provide a useful method of health promotion to assist with a decrease in health inequities. In Australia, a number of studies have identified education level rather than income as a better predictor of the distribution of urban greenery (Kendal, Williams et al. 2012).

Socioeconomic inequity and the diverse impacts of green space also make it difficult to measure economic benefits of green space using standard economic evaluation models (Botanic Gardens of South Australia, 2016). Many of these models assume that people make decisions that are reflected in financial ability and means, these assumptions don't hold well when it comes to housing affordability. Furthermore, the diverse impacts of green infrastructure make it difficult to provide comprehensive economic evaluation of benefits (VISES, 2015). Recent developments in Total Economic Value Frameworks that incorporate non-monetary benefits have begun to been developed within an ecosystem services framework (e.g. VISES, 2015). Further research is required to provide a more comprehensive understanding of the economic (monetary and non-monetary) benefits derived from green spaces including social (e.g. health) and environmental benefits that accrue at different scales (individuals, communities, institutions).

Culture

Relatively few studies have explored the importance of culture in shaping people's experience of public green spaces. A study from Turkey found some small differences such as locals placing more emphasis on passive recreation compared with western green space users (Özgüner 2011). However, the design of green spaces needs to change to meet the perceived needs of changing ethnic groups, and include the provision of areas for large community gatherings. Further research is needed to support this decision-making and supports the call to action from Thompson (2002) questioning the democratic role of green spaces in broader society.

Age

Studies have found that the relationship between urban green space and health varies across a person's life course (Astell-Burt, Mitchell et al. 2014). Older people have different needs for urban green spaces than younger people (Arnberger 2012, Astell-Burt, Mitchell et al. 2014). The design and planning of urban green space can have significant effects on the health and wellbeing outcomes for an ageing population and should be designed to accommodate age friendly cities and communities. Having walkable access to urban green spaces has also been shown to increase longevity of senior citizens (Takano, Nakamura et al. 2002).

Gender

There is mounting evidence that women and men experience and respond to urban green space in different ways (Astell-Burt, Mitchell et al. 2014). Some studies have found that women, perceiving themselves to be more vulnerable, were more fearful in urban green spaces compared to men (Sreetheran and van den Bosch 2014) and access to 'serene' green spaces has been shown to improve mental health in women but not men.

7. Important attributes of Green Public Open Space

There is relatively little research providing evidence of greenspace characteristics producing benefits. Some research suggests that accessibility or distance to green POS is an important predictor of use, that exposure to green POS can have some mental and physical health benefits and that vegetation structure and composition is important habitat and provides several ecosystem services (e.g. intercepting rainfall, cooling). Building evidence of greenspace correlates and thresholds would help in choosing evidence-based targets and the shaping of urban green space policy.

What is quality open space?

There is a well-established body of literature exploring how people perceive urban green POS. Environmental psychology literature shows that people consistently prefer natural scenes in cities compared to scenes that include built elements (Kaplan and Kaplan 1989). However, the mere presence of POS does not guarantee its benefits for people or for biodiversity (Francis, Giles-Corti et al. 2012).

Well-designed and good quality POS tends to attract more users and cater to a greater range of activities then poor quality spaces. Quality features of POS (not just green space) includes the presence of focal points such as the presence of trees, connected pathways and seating, nature, and the absences of litter and graffiti (Francis, Giles-Corti et al. 2012). A number of other studies have also found greater POS use in better quality parks when assessed using the POST tool (Giles-Corti, Broomhall et al. 2005, Edwards, Hooper et al. 2013). Indeed, Sugiyama and colleagues (2015) concluded that to encourage more recreational walking, building fewer higher quality parks was preferable to building a larger number of smaller lesser quality parks. High quality parks included grassed areas, amenities, dog-related facilities, and off-leash areas for dogs as well as gardens, walking paths, water features, and wildlife.

Other studies have shown that different kinds of people prefer different kinds of POS. For example, landscape preferences are based in values (Ives and Kendal 2013) and people who are environmentally focused or have ecocentric value orientations prefer wild landscapes, while people with more human-centred values prefer more managed landscapes. At a cultural level, people prefer landscapes with cues that conform to social or cultural norms. These preferences can be based on ethnic grouping. For example, people with an English background can prefer landscapes with shade trees while people from a Mediterranean background might prefer productive landscapes with edible plants and fruit trees (e.g. Fraser & Kenney, 2000).

Preferences can also be based on social norms and people's preference for messy, biodiverse landscapes can be improved by adding a neat 'frame' such as a fence or maintained edge that show the landscape is being cared for (Nassauer 1995). To satisfy the different needs and expectations of the community, a diverse 'portfolio of places' is needed to satisfy the broader community (Swanwick 2009, Thompson, Roe et al. 2012). and meet the needs of multiple users from children through to older adults (Giles-Corti, Ryan et al. 2012).

Another consideration for the design of quality open space is its ability to support ecosystem services and biodiversity. The vegetation and soil in urban green POS determines the capacity of the urban environment to support biodiversity (Threlfall, Ossola et al. 2016). Understanding the nature and variability of the vegetation within networks of green POS can help inform our knowledge of the distribution of the ecosystem services it provides and the composition of faunal communities that depend on it. It can also help prioritize strategic management of urban green POS vegetation so that it provides the greatest benefit to humans and to biodiversity (Fontana, Sattler et al. 2011, Threlfall, Ossola et al. 2016).

Development of a Green Space Matrix summarising the health and biodiversity benefits of green spaces

When planning for green spaces, managers and planners often consider the design requirements for human health, biodiversity and ecosystem services in isolation from each other. However, to build an equitable, liveable, healthy and resilient city, planners need to plan green spaces to achieve a multiple benefits including human health, biodiversity and ecosystem services. The following matrix (provided as Table 2 overleaf) is a tool that outlines the synergies and benefits of different landscape attributes provided by urban green space.

Table 2: The synergies and benefits of different landscape attributes provided by green space

ATTRIBUTES OF POS	Benefits From Green Open Space				
	PHYSICAL HEALTH	MENTAL HEALTH & WELLBEING	SOCIAL & CULTURAL	ECOSYSTEM SERVICES	BIODIVERSITY
Size & area	*Physical activity:* Large green POS with more amenities leads to greater levels of recreational physical activity. People with access to large attractive POS are more likely to achieve recommended levels of activity. *Quality design features of POS supporting physical activity*: grassed areas, amenities, trees, dog-related facilities, and off-leash areas for dogs as well as gardens, walking paths, water features, and wildlife.	*Perceptions of safety:* Can be more isolated in larger parks. Can reduce perceived safety when people don't feel visible. Designing to maximise natural surveillance is therefore important. *Wellbeing:* Better quality parks are thought to improve neighbourhood wellbeing.	*Sense of community:* Access to, and use of green POS appears to encourage a greater sense of community. *Conserving indigenous or European heritage:* Larger reserves may be able to preserve landscape level cultural features such as sightlines to surrounding hills. Small reserves may be able to adequately preserve specific artefacts such as buildings or other significant sites.	*Cooling, storm protection and noise reduction:* Larger areas of vegetation provide greater effects on cooling, storm protection and noise reduction. *Pollination:* Native bee species more likely to be found in large and less managed nature reserves and golf courses.	*Diversity of native species:* Larger areas of POS are likely to provide a variety of resources for plants and animals *Conservation of native ecosystems:* Large reserves can have some benefits (e.g. reduced edge effects, habitat for species with large ranges). Small reserves are effective in conserving some species and ecosystems, such as orchids and grasslands.
Accessibility & distance to a POS	*Physical activity:* Local access (<500 m) to green POS encourages recreational physical activity, although the size of POS appears to be important to achieve recommended levels of walking and small POS does not appear to encourage physical activity. Access to green POS with sports amenities is associated with higher physical activity in children. *Protective of diseases:* Access to	*Perceptions of safety:* The presence of safe road crossings to access POS is important to encourage use. *Wellbeing and general mental health:* Access to attractive POS including the presence of street trees, or views of green POS leads to reduced stress and mental fatigue *Childhood development:* Access to and use of green POS is thought to influence different	*Sense of community:* Access to, and use of green POS encourages a greater sense of community. *Conserving indigenous or European heritage:* Accessibility is important for many cultural heritage sites, although some spiritually important areas may exclude some groups of people (e.g. gendered indigenous sites).	*Cooling:* The cooling effect from vegetation decreases with distance from the green space. *Noise reduction:* Noise reduction is greatest when plantings are close to the source of the noise	*Conservation:* Conservation can reduce accessibility when people are excluded e.g. fencing. This may be justified in some cases such as the removal of rare orchids, or disturbance of migratory birds, but restricting access may not always be necessary and can limit the social benefits provided by conservation areas.

ATTRIBUTES OF POS	Benefits From Green Open Space				
	PHYSICAL HEALTH	MENTAL HEALTH & WELLBEING	SOCIAL & CULTURAL	ECOSYSTEM SERVICES	BIODIVERSITY
	and use of green POS is protective against several non-communicable diseases. *Physical healing:* In hospitals, access to nature can lead to faster surgical recovery and higher pain thresholds.	aspects of cognitive development in children, and enhance motor abilities.			
Trees	*Physical activity:* Trees – provide shade, and create more attractive POS which encourages walking.	*Perceptions of safety:* There can be public concerns about falling tree limbs. *General mental health:* Trees are associated with the mental health and wellbeing benefits of green space.	*Sense of community:* Street trees encourage a sense of community. *Conserving indigenous or European heritage:* trees can form important parts of cultural landscapes e.g. Avenues of honour, Lone Pine. Indigenous trees e.g. scar trees.	*Cooling:* Trees canopy coverage is a good predictor of the cooling effects of urban green space. *Storm protection:* Trees provide protection to infrastructure during storm events. *Air quality:* Trees can filter atmospheric particulates, although trees can also trap pollution in street canyons, and some trees emit BVOCs.	*Habitat for native animals:* Old trees with hollows offer habitat for birds and mammals, and trees more generally offer habitat for arthropods. *Conserving ecosystems and native species:* Trees can be conserved in their own right, and provide habitat for many species. Native trees can provide habitat for native bird species.
Lawn	*Quality design features of POS supporting physical activity*: Grassed areas provide areas for active and passive recreation, including active sports and off-leash areas for dogs.	*Landscape preference:* Parks with scattered trees in lawn are generally preferred.	*Cultural preferences:* Lawns are an important part of some western landscapes in cool-temperate regions, such as the UK and the USA, but are much less important in many other cultures.	*Cooling*: Irrigated grass can provide cooling benefits. *Pollution*: Turf maintenance can cause high levels of carbon emissions, and chemical pollution through the use of pesticides, herbicides and fertilizers.	*Biodiversity*: Lawn has negative effects on native biodiversity, with mown lawn providing little habitat for many mammals, birds or insects. However, unmanaged long grass can provide important habitat for insects.

	Benefits From Green Open Space				
ATTRIBUTES OF POS	**PHYSICAL HEALTH**	**MENTAL HEALTH & WELLBEING**	**SOCIAL & CULTURAL**	**ECOSYSTEM SERVICES**	**BIODIVERSITY**
Social infrastructure i.e. provision of paths, lighting seating, water fountains, BBQ, seating, tables.	*Physical activity:* A range of amenities encourages physical activity and recreational walking. In adolescents, access to skate parks and lighting around sports areas encourages greater participation in physical activity.	*Perceptions of safety:* Visible signs of maintenance is important as features and facilities in disrepair contribute to a perceived lack of safety; and discourage recreational walking.	*Social connectedness:* Views of green areas from home increases perceived social connection. Public art, connected pathways, playgrounds, seating and the absence of graffiti and litter is also thought to increase connection.	*Water sensitive urban design:* Water features in public open space can be used to filter stormwater. *Sustainability*: Energy and resource requirements should be considered across the complete lifecycle of infrastructure.	*Biodiversity*: Lighting can interrupt the lifecycles of some species, and keeping some areas free from lights is important to maintain populations of some species.
Habitat & vegetation complexity	*Physical activity:* Varied vegetation and topography facilitates different types of spontaneous play for children i.e. tree climbing, building cubbies or playing house or pirates. Gardens and grassed areas also important.	*Perceptions of safety:* Vegetation that obscures the visibility of surrounding houses and roads can reduce perceptions of perception of safety. Designing POS with natural surveillance by having surrounding houses overlooks parks increases perceptions of safety; and reduces disorder.	*Sense of community & sense of place:* Natural areas with complex vegetation can encourage sense of community and connection to local natural heritage.	*Pollination:* Habitat and vegetation complexity benefits a diversity of pollinators. *Stormwater and noise attenuation*: Structural complexity of vegetation helps to reduce stormwater runoff and attenuate a wider frequency of noise.	*Habitat:* Complexity has positive benefits for many species of animals including birds, reptiles and arthropods. The presence of leaf litter, logs, long grass, old trees and native vegetation is generally beneficial.
Irrigation	*Physical activity:* Attractive parks that are irrigated encourage more recreational walking.	*Mental health:* Lush green vegetation aids the health and wellbeing benefits of green space, and is generally preferred by people.	*Community use*: Irrigated areas of lawn can provide suitable areas for community picnics and outdoor events.	*Cooling:* Irrigated areas of lawn and irrigated trees can increase cooling.	*Biodiversity:* Irrigation can allow a wider range of plant species to grow, but can be detrimental where it advantages non-local species over local species.
Hetero-geneity	*Physical activity:* Neighbourhoods with greater variation in greenery have been shown to	*Mental health*: Different kinds of people respond to different kinds of landscapes. Having a range of	*Social activities:* Having a range of green space types provides opportunities for a wider range of	*Resilience*: While having variation in urban greenery can reduce total service provision, it can increase	*Biodiversity*: Heterogeneity in urban greenery is critical to support a range of different kinds of organisms.

	Benefits From Green Open Space				
ATTRIBUTES OF POS	PHYSICAL HEALTH	MENTAL HEALTH & WELLBEING	SOCIAL & CULTURAL	ECOSYSTEM SERVICES	BIODIVERSITY
	decrease the risk of hospital admissions for cardiovascular disease and stroke. Adolescents with access to a variety of POS within 800m of their homes, have been found to achieve more MVPA.	landscapes provides mental health and wellbeing benefits to a wider range of people.	social activities, such as dog walking, nature appreciation, active sports, and recreational walking.	resilience to external shocks such as changing temperatures or storms and floods.	

8. At what scale do green space benefits need to be planned?

The large scale benefits of green space are multidimensional and include benefits for human health and wellbeing, ecosystem services and biodiversity. However, each of these benefits have different requirements at different scales and will be constrained by differing urban planning, policy, management and practice requirements. Appropriate planning needs to be based on achievable objectives at different geographic levels of scale including city, region, suburb, neighbourhood and site. For example, at very small scales ecosystem benefits might require conservation reserves focusing on native biodiversity improvements or conservation of threatened species while physical activity benefits could focus on improved park quality and amenities at local parks and sports fields.

This scaled approach to planning has previously been suggested by the UK government in their approach to management of green spaces and has been described as a hierarchical policy framework (Sadler, Bates et al. 2010). The policy was designed out of need for a clearer management and understanding of the provision, quality and access to green space in cities and the hierarchical system linked strategies within policies at the national, regional, sub-regional, local, neighbourhood and site level. A similar approach is recommended in this report and a hierarchical approach is provided in Table 3 overleaf.

Appropriate planning at different scales according to city, region, neighbourhood, site, and sub-site is required and should be considered as part of an interconnected system of green space provision rather than planning at individual isolated scales. It is important to note that green spaces at neighbourhood or site scales do not need to provide all benefits, depending on the context and surrounding strengths and benefits of the area. For example, residential neighbourhoods will have different green space requirements compared with largely industrialised neighbourhoods.

Table 3: Hierarchical green space benefits at different geographic scales.

	Physical Activity Benefits	Mental Health Benefits	Social Benefits	Cooling Benefits	Biodiversity Benefits
City scale	Green spaces should be design to provide all benefits within a city				
	↓				
Regional scale	Green spaces should be design to provide all benefits within every region				
	↓				
Neighbourhood scale					
Residential	Benefits should be provided in all residential areas				Possibly e.g. biodiversity can be conserved to improve people's connection to nature
Commercial	Possibly – e.g. shared paths for commuting	Possibly e.g. spaces to relax	Yes		
Industrial		e.g. amenity plantings	Possibly e.g. lunch facilities	Yes	Possibly e.g. preserve remnant patches
	↓				
Site scale					
Park	Yes	Yes	Yes	Yes	Maybe
Linear reserve	Yes	Maybe	Yes	Maybe	Maybe
Streetscape	Maybe	Maybe	Yes	Yes	Maybe
Conservation reserve	Maybe	Maybe	Maybe	Maybe	Yes
Sports field	Yes	Maybe	Yes	Maybe	Maybe
	↓				
Sub-site scale					
Park	e.g. construct shared paths	e.g. add garden beds	e.g. add picnic tables	e.g. plant more trees	e.g. plant local species
Linear reserve		e.g. quality design	e.g. add rest nodes		
Streetscape	e.g. plant shade trees to promote walking				
Conservation reserve	e.g. construct shared paths	e.g. quality design	e.g. support friends group		Yes
Sports field	Yes	e.g. add garden beds	Yes		e.g. preserve remnant patches, undertake ecological restoration

9. Recommended principles to achieve co-benefits from green space for health, biodiversity and ecosystem services

For people living in large and dense cities, a good quality of life is influenced by the quality of the urban environment (Van Leeuwen, Vreeker et al. 2005). The attributes that determine the 'quality' open space are likely to be different for different people, and will lead to different outcomes for biodiversity and ecosystem processes. There are diverse benefits associated with access to urban green space. These attributes and benefits cannot be simply summarised as a one straightforward relationship (WHO, 2016), though consistently larger greens spaces are indicated for better physical health as well as biodiversity outcomes and urban cooling impacts.

The quality of and benefits derived from POS depend on what that space is trying achieve. Different POS have different purposes and below we outline several principles derived from the literature review which should be applied in best practice urban greening planning and management. However, for both physical and environmental health, consistent with the views of some authors it appears that having access to fewer larger high quality POS may be more beneficial, than access to a large number of smaller poorer quality POS (Sugiyama, Gunn et al. 2015). Nevertheless, some important principles appear to apply:

Principle 1: Promote and protect community and environmental health

The general public and policymakers need to be educated about the factors that influence human and ecological wellbeing in the future design of green spaces. This review summarises an extensive research literature that is not currently being widely applied in urban planning and practice. Community awareness and knowledge translation activities are necessary to inform future practice before strategic planning and community consultation activities occur. Providing materials that communicate these benefits in plain language is strongly recommended.

Principle 2: Identify community needs

People value green POS for a range of different reasons that vary with socioeconomics, culture and across the life course; this spectrum of values and activities must be considered when planning green POS (Ives, Oke et al. 2014). It is increasingly agreed that green open space networks need to be tailored to the specific needs of the communities Applying standards such as providing a certain amount of green space per resident might fail to consider other important factors identified throughout this report such as the quality and accessibility of the space - both of which are known to influence use and the benefits provided by urban green spaces across the life course.

Identifying the needs of the current and predicted future community is considered practical and proactive for planners to achieve best practice POS and green space planning. Community engagement in the planning and design of green spaces is an important step in understanding these needs. Engagement not only encourages community ownership of the open space, but may also maximise its use.

Community engagement should occur at various stages of the planning processes, including initial needs-based assessment and throughout planning and implementation stages (Ives, Oke et al. 2014) It is also important that the views of non-users are taken into account as certain benefits of green open space (such as biodiversity conservation) might be important to these members of the community, even if they do not visit parks (Ives, Oke et al. 2014).

Anticipating the needs of future communities is critical when planning green open space networks in new suburbs, high density areas and regional growth areas. Sports and Recreation Tasmania (2010) identified the following key factors influencing open space needs for communities: i) economic development and affluence; ii) community debt; iii) population growth; iv) work hours and employment structure; v) family structure; vi) home and living styles; vii) population age structures; viii) cultural diversity, ix) education levels; and x) housing affordability and diversity. Anticipating the demographics of people likely to use space is critical when planning for changing communities or a community yet to exist.

Principle 3: Understand the network of green spaces

The human health, biodiversity and ecosystem service benefits of green spaces are strongly related to its proximity, accessibility and connectivity. Moreover, use of green space by residents is enhanced when linked to neighbourhood destinations through green corridors such as walking and cycling paths. Connecting green spaces through these corridors also provides habitat and safe corridors for movement of animals and dispersal of plants. While Local Government Areas (LGAs) are the scale at which POS networks are most commonly planned and developed, it is important to consider surrounding regions both for ecological connectivity and for people living in adjoining LGA's.

Principle 4: Heterogeneity as a target

The importance of preserving natural plant communities within cities is becoming increasing realised. Areas of native vegetation in cities are considered important for several reasons including breaking down homogeneity of landscape design as natural area are visually different from traditional parks and gardens and create a local identity and sense of place.

Principle 5: Consider biodiversity outcomes

Cities are often considered poor areas for biodiversity. However, as this literature review has demonstrated, there is mounting evidence that urban areas sustain a diversity of plant, animal and invertebrate populations, including threatened species. In some cases, the diversity of plants and animals can be higher in cities than the surrounding landscape with cities supporting a larger presence of both exotic and native species (Ives, Lentini et al. 2016). Biodiversity can be supported and conserved at a range of scales, from the presence of street trees, to larger regional parks.

Principle 6: Maximising the quality of POS

In addition to a focus on the amount of POS in a community, greater consideration needs to be given the quality and maintenance of those spaces, as there is evidence that this is important for both physical and mental health. Good quality green spaces within POS should include features such as trees, gardens, walking paths, grassed areas, amenities, dog-related facilities and off-leash areas, water features and wildlife. For biodiversity, good quality open space should include a variety of habitats, structural complexity in understorey vegetation, and specific habitat features such as tree hollows. Threatened species and ecological communities should be preserved and supported where they occur.

Principle 7: Plan for maintenance and irrigation

Green space and POS strategies need to be planned in accordance with climate and irrigation needs. Irrigation of Public Open Space guidelines must be made available to all authorities associated with long term management and maintenance and have flexibility to adapt to climatic and environmental changes such as drought.

Principle 8: Type and scale of green spaces

Design and implementation of green space needs to be developed with an understanding of how different green spaces are needed to achieve different types of health and environmental benefits at specific geographical scales across cities. One type of green space cannot meet all possible health and biodiversity benefits and different designs across multiple geographies will produce the greatest positive impact.

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Appendix 1: Categories of Public Open Space

The categories of POS included in this table are adapted from Parks and Leisure (2013) open space by its broad primary land use and highlights that open spaces planning should not be undertaken in isolation from broader land use planning processes.

Types of POS	Landscape character	Public Open Space Use
Conservation and Heritage	Conservation, protection or enhancement or natural or semi-natural character e.g. Nation/State parks, regional/ metropolitan parks, areas of remnant vegetation	Unstructured recreation (walking/ cycling), nature appreciation, heritage appreciation, fire management, research
Natural or semi natural, landscapes and amenity	Land that adds or protects the character of the area with some environmental or cultural value e.g. wetlands, stream frontages, historic areas, ridge lines, habitat corridors	Recreation compatible with semi natural landscapes (e.g. walking, cycling), nature appreciation, research, water management, fire management
Parklands and gardens	Land with some modification to support community social interaction and unstructured recreation e.g. landscaped parks and gardens, formal lawn areas, playgrounds, pocket parks, botanical gardens	Structured and unstructured activities and community recreation. Community events, community gardens, picnics, celebrations, play
Linear open space and trails	Established to ensure effective functioning of natural processes, to protect fauna and flora corridors and OR provide links to open space networks e.g. rivers, creeks, drainage easements, coastal reserves, habitat corridors	Walking, cycling, commuter travel, nature appreciation, informal recreation
Active open space	Sports e.g. sports fields, bowling greens, tennis, netball, athletics tracks	If appropriately planned with walking paths around the perimeter and play equipment for children, these can encourage recreational walking and active play for children, while also meeting the needs of formal sports.
Civic spaces	Civic squares, plazas, promenades	Organised events, passive use for workers, civic events, dining, entertainment, public expos
Utilities and services	Pipe easements, power line easements, railway line buffers, cemeteries/ memorials, dams	Linear trails, habitat corridors, sports fields
Undeveloped/ proposed	Former landfill site, industrial areas, former school sites	Not yet identified
Coastal land and beaches	Open space that forms part of the foreshore and parklands	Beach recreation, conservation, walking, cycling, nature appreciation, informal recreation
Plantations	Land primarily for tree growing e.g. forestry, water catchment	Often with limited public access, but could include recreation compatible with semi natural landscapes (e.g. walking, cycling), nature appreciation, research, water management, fire management