Living Melbourne

Our metropolitan urban forest

Technical Report

April 2019

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1 Introduction

1.1 What is the metropolitan Melbourne urban forest?

The urban forest comprises trees, shrubs, grasslands supported by soil and water and other vegetation growing on public and private land across metropolitan Melbourne. This includes vegetation within parks, reserves and private gardens along railways, waterways, main roads and local streets, and on other green infrastructure such as green walls and roofs. The urban forest encompasses all types of vegetation and ecosystems, but one of the most iconic elements is its trees and shrubs. Fauna is an important component of the urban forest, with complex interrelations between animals and plants helping to maintain the urban forest.

1.2 What is the purpose of the technical support document?

The purpose of this technical support document is to provide the evidence base that underpins the *Living Melbourne* strategy. The sections of this document include:

Section 1 – Introduction

Section 2 – Provides a discussion about why biodiversity is important, and the type and distribution of biodiversity in metropolitan Melbourne.

Section 3 – Discusses the ecosystem services and benefits that the urban forest brings to metropolitan Melbourne's community.

Section 4 – Discusses the value of Melbourne's urban forest and outlines some of the risks that it faces; considers the importance of Water Sensitive Urban Design and explores how urban development has shaped our urban forest; summarises some of the current actions, both singular projects and collaborative activities, that local governments and others are undertaking to manage our urban forest, and provides examples of urban forest management internationally.

Section 5 – Summarises the key policy frameworks or relevant strategies that influence the urban forest.

Section 6 – Provides analyses of the vegetation across metropolitan Melbourne by height and distribution, the public accessibility of our open space assets, and the associated biodiversity modelling.

Section 7 – Provides analysis of the heat mapping mapping incuding modelling of the hot spots and cool spots across metropolitan Melbourne and the methodology of that analysis.

Section 8 – Provides an analysis of the modelling of bird species or bird group distribution and the methodology of that modelling.

Section 9 – Describes existing vegetation measurement and monitoring activities; provides summaries of common urban forest metrics used internationally, and of joint measuring and monitoring platforms that have been developed.

Section 10 – Describes existing financial mechanisms and new options to finance the implementation of this strategy.

Section 11 – Provides an initial list of tools and resources that may assist practitioners in the protection, enhancement and expansion of the urban forest based on feedback received during the development of *Living Melbourne.*

2 Biodiversity and conservation across metropolitan Melbourne

2.1 What is biodiversity?

Biodiversity is defined in Protecting Victoria's Environment – Biodiversity 2037 plan as encompassing 'all components of the living world: the number and variety of plants, animals and other living things (including fungi and micro-organisms) across our land, rivers, coast, and ocean. It includes the diversity of their genetic information, the habitats and ecosystems within which they live, and their connections with other life forms and the natural world.' This definition applies to *Living Melbourne*.

Please note that all flora and fauna data records in this section are drawn from the Victorian Biodiversity Atlas (Victoria State Government, n.d.).

2.2 Urban biodiversity in a global context

The world is experiencing unprecedented urban growth. Today, just over half of the world's population (55%) lives in urban areas, and this is predicted to rise to just over two-thirds (68%) by 2050 (United Nations, n.d.). Urban areas currently occupy approximately 3% of the Earth's land surface (McDonald, et al., 2013). Cities are home to billions of people who depend on healthy, natural systems to provide clean water, food, flood protection and resources for industrial, recreational and other uses. The suitability of urban areas for human occupation relies on the presence of natural areas that sustain biodiversity within and outside their borders. A growing global population and an increasing trend toward urbanisation are placing higher demands on the natural systems in and around urban areas.

Despite the known broadscale trends in urban growth, there is still much to learn about the consequences of urbanisation for biodiversity and how best to design cities and towns to conserve biodiversity and maintain healthy ecosystems (Ossola & Niemela, 2018). Until relatively recently, urban areas were thought to be of low value for biodiversity, but evidence is increasingly showing that urban and suburban areas can, in fact, support relatively high levels of biodiversity (Alvey, 2016). For example, a recent study by Ives et al. (2016) found that over 30% of Australia's threatened plants and animals occur in urban areas (Ives, et al., 2016). However, best practice guidelines are lacking for how to halt biodiversity loss or increase biodiversity in these areas (Threlfall, et al., 2017).

According to the Cities and Biodiversity Outlook of the Secretariat of the Convention on Biological Diversity (2012), there are some interesting patterns in urban biodiversity:

1. The number of plant species in urban areas often correlates with human population size more than it does with the area of the city.
2. The age of the city affects species richness: large, older cities have more plant species than large, younger cities.
3. Species diversity appears to be correlated with economic wealth. For example, in Phoenix, USA, plant and bird diversity in urban neighbourhoods and parks showed a significant positive correlation with median family income (Kinzig, et al., 2005). Interestingly, recent research from Australia suggests that education levels may play a more important role than income (Kendal, et al., 2012).
4. Approximately 20% of the world's bird species and 5% of the vascular plant species occur in cities.
5. On average, 70% of plant species and 94% of bird species found in urban areas are native to the surrounding region. A 2014 study similarly found that most species of birds and plants in cities

globally are native to that area (Aronson, et al., 2014). However, the study also found that the density of native urban species has declined substantially to only 8% and 25% of the typical non-urban density for native birds and native plants, respectively. This disparity was primarily caused by anthropogenic factors (landcover, city age) rather than by non-anthropogenic factors (geography, climate, topography). The authors suggest that despite the reduction in the density of native species, many cities still provide important opportunities for regional and global biodiversity conservation, restoration and education.

2.3 Geography and history of metropolitan Melbourne

Melbourne is located at the junction of seven different bioregions (see Section 2.4.1). Prior to European settlement, the area that is now metropolitan Melbourne was covered in a rich mosaic of different plant communities that ranged from grasslands and open grassy woodland on the cracking clay soils of the west to coastal heathland and heathy woodlands in the southeast, and moist temperate forests and rainforests in the area now known as the Dandenong Ranges. Rivers, creeks, wetlands and swamps added further complexity and richness of habitats to the area. This diverse mosaic arose through a combination of different soils, environmental conditions, and the land management practices of the Woiwurrung (Wurundjeri), Boon Wurrung, and Wathaurong peoples of the Kulin Nation, who are the Traditional Owners of the land now known as Melbourne, and who have spent millennia caring for country.

Since the European settlement of Melbourne in 1835, the city has experienced profound changes due to fluctuating economies, industrialisation, population growth, and other social and political factors. British colonial influences were the primary driver of the development of Melbourne as a city, and economic wealth was largely derived from the gold rush that started in the mid-1800s. This period saw the establishment of large areas of green space and parks that were carefully planned and landscaped (Ives, et al., 2013), giving the inner suburbs the leafy green feel they are known for today. Population growth, manufacturing, and commercial development over subsequent decades led to the city's rapid expansion (*Figure 1*) and established a steady pattern of converting agricultural land into residential land along the fringes. High levels of car ownership and the availability of 'cheap' land on the urban-rural fringe continues to drive this pattern today. The proportion of Melbournians within 10 kilometres of the General Post Office (GPO) has increased from 30% in 1954 to 84% in 2001 (Department of Planning and Community Development 2004, cited by Ives et al. (2013)) (Ives, et al., 2013). Consequently, urban sprawl is one of the biggest challenges that Melbourne faces with respect to sustainability and conserving biodiversity. Another major challenge is increased densification of existing suburbs, often through the conversion of single-dwelling house-lots into multi-unit developments.

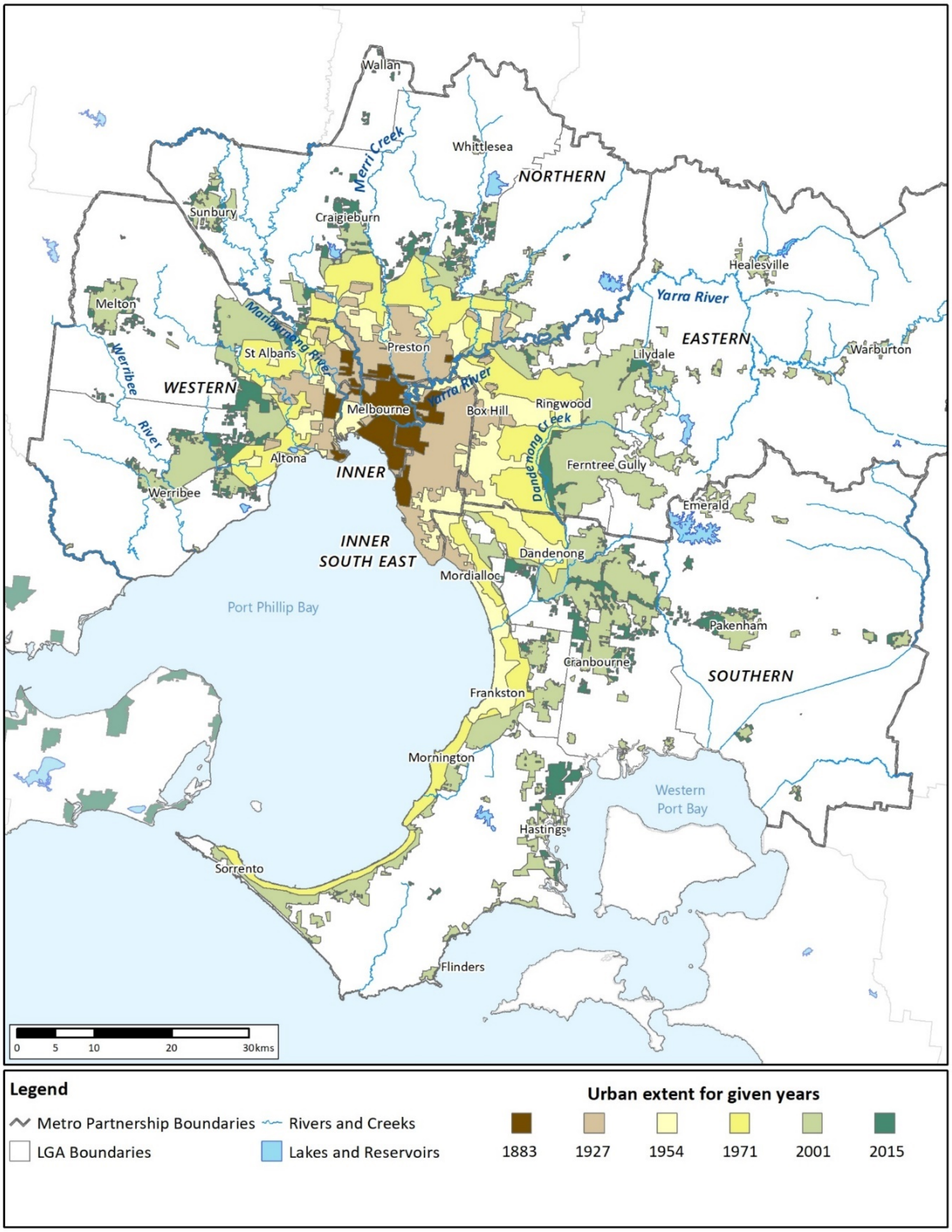


Figure 1. **The growth and expansion of Melbourne since European settlement in 1883. (Data Source: Copyright © The State of Victoria, Department of Environment, Land, Water & Planning 2019)**

While much of metropolitan Melbourne has been substantially modified and irreversibly changed by urbanisation, the metropolitan area retains substantial natural values and a high diversity of flora and fauna (Victorian Environmental Assessment Council, 2011). The historical development pattern of Melbourne has enabled a range of indigenous and non-indigenous species to persist in the urban environment. This pattern includes the retention of one of the highest percentages of open green space of any city in the world at more than 28%, including Crown road reserves (Victorian Environmental Assessment Council, 2011). In addition, 26% of metropolitan Melbourne (both public and private land) contains native vegetation (Victorian Environmental Assessment Council, 2011). However, a study of a more constrained area of the Melbourne @2030 urban growth boundary found that inner city areas only retained approximately 1.6% of the original vegetation cover compared to the outer suburbs with 16% (Hahs, et al., 2009). Despite the relatively high area of public open space and overall native vegetation cover, many species of native flora and fauna have declined (Hamer & McDonnell, 2010), (van der Ree & McCarthy, 2005), and further loss can be expected due to a significant extinction debt unless additional effort is put into sustaining plant populations (Hahs, et al., 2009).

2.4 Biodiversity of metropolitan Melbourne

2.4.1 Bioregions

Melbourne sits at the junction of seven bioregions, which are broad geographical regions composed of clusters of interacting ecosystems that share common physical and biological features such as climate, geology, landforms, soils and vegetation (Figure 2). Most of the metropolitan Melbourne Urban Forest study area falls within the Gippsland Plain, Highlands Southern Fall, and Victorian Volcanic Plain bioregions, with smaller areas of the Otway Plain, Central Victorian Uplands, Victorian Alps and Highlands-Northern Fall bioregions (Table 1). Summary descriptions of each bioregion can be found within the Victorian Environmental Assessment Council (VEAC) Final Report (Victorian Environmental Assessment Council, 2011).

Figure 2. Map of the Living Melbourne study area showing the bioregions and extent of remaining indigenous vegetation (Data Source: Copyright © The State of Victoria, Department of Environment, Land, Water & Planning 2019)

Table 1. Extent of Victorian Bioregions within the Living Melbourne study area

Bioregion	Area (km^2)
Central Victorian Uplands (CVU)	247.8
Gippsland Plain (GP)	3,489.9
Highlands - Northern Fall (H-NF)	263.2
Highlands - Southern Fall (H-SF)	3,639.9
Otway Plain (OP)	168.0
Victorian Alps (VA)	63.9
Victorian Volcanic Plain (VVP)	2,590.3
Grand Total	10,463.1

2.4.2 Native Vegetation - Ecological Vegetation Classes

Ecological Vegetation Classes (EVC) are the standard units for classifying vegetation types in Victoria. EVCs are described using a combination of floristics, lifeform, and ecological characteristics, and through an inferred fidelity to particular environmental attributes (Department of Environment Land Water and Planning, n.d.). There are approximately 300 EVCs in Victoria, 85 of which occur within the VEAC Metropolitan Melbourne investigation area (Victorian Environmental Assessment Council, 2011). Many of these EVCs also occur outside of the investigation area and within adjoining bioregions.

The *Living Melbourne* study area contains a total of 93 recognised EVCs of native vegetation. These 93 EVCs fall into 17 groups and cover a total of 2,897.5 square kilometres, or 27.6% of the study area (*Table 2*). This number includes the Mornington Peninsula and western half of the Yarra Ranges local government areas and is therefore slightly larger than that observed in the VEAC Metropolitan Melbourne investigation area.

Table 2. Extent of native vegetation (hectares) within the Living Melbourne study area in each EVC Group per bioregion. The bioregions are: Central Victorian Uplands (CVU), Gippsland Plain (GP), Highlands - Northern Fall (H-NF), Highlands - Southern Fall (H-SF), Otway Plain (OP), Victorian Alps (VA), Victorian Volcanic Plain (VVP)

EVC Group	Bioregion							
	CVU	GP	H-NF	H-SF	OP	VA	VVP	Grand Total
Box Ironbark Forests or dry/lower fertility Woodlands	11.0	0.1	0.0	10.9	0.0	0.0	4.1	26.1
Coastal Scrubs Grasslands and Woodlands	0.0	42.2	0.0	0.0	0.3	0.0	0.5	42.9
Dry Forests	44.8	41.3	52.0	619.3	0.0	0.0	6.1	763.4
Heathlands	0.0	5.8	0.0	19.9	0.0	0.0	0.0	25.7
Heathy Woodlands	0.0	46.2	0.0	63.1	0.0	0.0	0.0	109.2
Herb-rich Woodlands	0.0	24.4	0.0	25.9	0.0	0.0	0.1	50.5
Lower Slopes or Hills Woodlands	15.4	54.8	0.0	4.9	0.0	0.0	6.9	81.8
Lowland Forests	0.0	42.7	0.0	213.4	0.0	0.0	0.0	256.2
Plains Grasslands and Chenopod Shrublands	0.0	10.3	0.0	0.0	0.2	0.0	230.9	241.4
Plains Woodlands or Forests	1.5	7.0	0.0	5.6	2.6	0.0	79.5	96.3
Rainforests	0.0	0.0	8.3	24.1	0.0	2.6	0.0	34.9
Riparian Scrubs or Swampy Scrubs and Woodlands	4.3	91.8	4.3	192.8	0.0	0.0	9.8	303.0
Riverine Grassy Woodlands or Forests	0.4	6.8	0.0	7.4	1.7	0.0	8.5	24.7
Rocky Outcrop or Escarpment Scrubs	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.2
Salt-tolerant and/or succulent Shrublands	0.0	24.2	0.0	0.0	1.2	0.0	10.8	36.2
Wet or Damp Forests	0.0	2.9	119.0	619.0	0.0	47.9	0.0	788.7
Wetlands	0.0	9.0	0.0	0.0	0.3	0.0	6.9	16.3
Grand Total	77.3	409.5	183.6	1,806.4	6.2	50.5	364.0	2,897.5

EVCs that occur in multiple bioregions may have different ratings of Bioregional Conservation Status (BCS) in each because their prevalence in each bioregion varies. For the *Living Melbourne* study area, there are a total of 202 recognised combinations of EVCs by bioregion; 94 of these are considered Endangered, and 49 are considered Vulnerable (*Table 3*). The Gippsland Plains Bioregion contains the largest number of Vulnerable or Endangered EVCs (20 Vulnerable and 32 Endangered), followed by the Victorian Volcanic Plain (10 Vulnerable, 31 Endangered) and Highlands-Southern Fall (11 Vulnerable, 10 Endangered). This pattern largely reflects the proportion of the study area covered by these three dominant bioregions, and also highlights the need to consider how the metropolitan Melbourne Urban Forest Strategy can contribute to supporting and enhancing the health of these important native vegetation communities so that they can continue to persist into the future.

Table 3. Bioregional Conservation Status (BCS) of each EVC within the metropolitan Melbourne Urban Forest Strategy study area by bioregion. LC - Least Concern, D - Depleted, R - Rare, V - Vulnerable, E - Endangered, na - insufficient information

Bioregion	LC	D	R	V	E	na	Total
Central Victorian Uplands (CVU)	3	4		7	9		23
Gippsland Plain (GP)	5	8	3	20	32		68
Highlands - Northern Fall (H-NF)	9	2		1	2		14
Highlands - Southern Fall (H- SF)	11	4		11	10	1	37
Otway Plain (OP)					9		9
Victorian Alps (VA)	3		1		1		5
Victorian Volcanic Plain (VVP)	1	3		10	31	1	46
Grand Total	**32**	**21**	**4**	**49**	**94**	**2**	**202**

2.4.3 Flora of metropolitan Melbourne

Metropolitan Melbourne supports a diverse array of native plants. A report by VEAC (2010) found that, since 1990, 1,753 native vascular plant species have been recorded within the metropolitan Melbourne investigation area (which excludes the Shires of Yarra Ranges or Mornington Peninsula). The report noted that the study area, which represented only 2.5% of Victoria, contained records of 40% of all Victorian native plant species (Victorian Environmental Assessment Council, 2011). When including the areas of the Mornington Peninsula and the western half of the Yarra Ranges, Ives et al. (2013) put the figure at 1,864 native plants in the combined area (Ives, et al., 2013). In addition to vascular plants, the VEAC investigation also recorded 840 species of bryophyte (mosses and liverworts), lichen, and fungi (Victorian Environmental Assessment Council, 2011). Of all the flora species found within metropolitan Melbourne, 178 are considered threatened (Ives, et al., 2013).

The metropolitan Melbourne area also hosts a diverse array of introduced plants (Ives, et al., 2013), and 1,100 species have been recorded within the VEAC investigation area (Victorian Environmental Assessment Council, 2011). Introduced plants represent approximately one third of all plant species within the metropolitan area.

The high diversity of plants in metropolitan Melbourne has been attributed to several factors. These include the high proportion of open space, the diversity of habitats present due to its location at the junction of three major geological formations and seven bioregions, the unique biodiversity of Australia, and the way in which historical planning decisions have influenced the development of the city (Ives, et al., 2013), (Victorian Environmental Assessment Council, 2011).

Within the Department of Environment, Land, Water, and Planning (DELWP) Port Phillip Region, which includes 31 metropolitan municipalites (but not Mitchell Shire Council), a total of 3,496 plant species have been recorded since 1998. Thirty-nine per cent of these species were introduced to Victoria, reflecting the significant changes that have occurred in the region since European settlement. This region also supports a high diversity of ferns and allied plants, as well as cryptogams such as mosses and liverworts, the majority of which are native to the region (Table 4).

Table 4. **The number of records within the Victorian Biodiversity Atlas for plant species in the DELWP Port Phillip region recorded since 1 January 1998.**

	Vascular Plants	Ferns and Allies	Liverworts	Mosses
Native	2143 (61%)	101 (92%)	96 (100%)	199 (98%)
Introduced	1353 (39%)	9 (8%)	0 (0%)	4 (2%)
Total	3496 (100%)	110 (100%)	96 (100%)	203 (100%)

2.4.4 Fauna of metropolitan Melbourne

Metropolitan Melbourne is situated at the junction of seven bioregions, and the species richness of its fauna reflects this. For example, the area features 21 of Victoria's 23 species of bats, and some of these are at home in bioregions that predominantly occur outside metropolitan Melbourne.

Within the DELWP Port Phillip Region, a total of 27 native amphibian, 45 native reptile, 43 native mammal, and 355 native bird species have been recorded since 1998 (Table 5). A total of 185 native invertebrate species have also been found, but this number is likely to significantly underestimate the actual diversity of invertebrates in the region.

Table 5. **The number of Victorian Biodiversity Atlas records for animal species in the DEWLP Port Phillip region recorded since 1 January 1998.**

	Amphibians	Bats	Birds	Mammals	Reptiles	Invertebrates*	Fishes
Native Species	27	21	355	43	45	185	88
Introduced Species	0	0	22	17	0	1	13
Grand Total	27	21	377	60	45	186	101

* These values are likely to be significant underestimates of the actual number of invertebrate species in the metropolitan Melbourne area.

2.4.5 Threatened species and ecological communities in metropolitan Melbourne

Australia's urban areas support over 30% of our rare and threatened plant and animal species (Ives, et al., 2016). The DELWP Port Phillip Region is home to 34 species of plants that are listed under the Federal Government's *Environment Protection and Biodiversity Conservation (EPBC) Act 1999*, and 64 species of plants that are listed under Victoria's *Flora and Fauna Guarantee (FFG) Act 1988*). Examples of listed plants include the Spiny rice-flower (*Pimelea spinescens subsp. spinescens*), the Round-leaf Pomaderris (*Pomaderris vacciniifolia*) and the Kilsyth South Spider Orchid (*Caladenia sp. aff. Venusta*); all are listed as Critically Endangered in Australia and Endangered in Victoria.

Table 6. Number of plant species listed on the federal Environmental Protection Biodiversity Conservation (EBPC) Act 1999, and the Victorian Flora and Fauna Guarantee (FFG) 1988 Act.

	Higher Plants	Ferns and Allies	Liverworts	Mosses
EPBC Act listed	34	0	0	0
FFG Act listed	64	2	1	0

Within the DELWP Port Phillip Region, 52 species of wildlife are listed under the *EPBC Act* and 95 species under the *FFG Act* (Table 7). Five animal species are listed as Critically Endangered both on the *EPBC Act* and the *FFG Act*, namely the Golden Sun Moth (*Synemon plana*), the Regent Honeyeater (*Anthochaera phrygia*), the Helmeted Honeyeater (*Lichenostomus melanops cassidix*), the Orange-bellied Parrot (*Neophema chrysogaster*) and the Plains-wanderer (*Pedionomus torquatus*).

Table 7. Number of fauna species listed on the Federal Environmental Protection Biodiversity Conservation (EBPC) Act 1999, and the Victorian Flora and Fauna Guarantee (FFG) Act 1988.

	Amphibians	Bats	Birds	Mammals	Reptiles	Invertebrates*	Fishes
EPBC listed	2	1	27	11	3	2	6
FFG listed	3	5	55	13	4	5	10

2.5 Sites of Significance

The metropolitan Melbourne area includes several Sites of Significance related to biodiversity that is listed under the *Convention on Wetlands of International Importance (the Ramsar Convention) 1971*. These include eight National Parks, Port Phillip Heads Marine National Park, Coastal Reserves in Port Phillip Bay and Western Port, and the Edithvale-Seaford Wetlands (Figure 3). These wetlands and coastal reserves are important habitat for migratory birds.

There are also over 200 bushland, grassland and other nature reserves across metropolitan Melbourne, many of which support important populations of plant and animal species (http://creativecommons.org/licenses/by/4.0/, n.d.). These range in size from small spaces of less than 0.5 hectare to large spaces, such as the proposed 15,000 hectare Western Grassland Reserve. These additional areas of native vegetation provide a network of resources and habitat for plants, birds, frogs, insects and other species, and play an important role in supporting Melbourne's biodiversity.

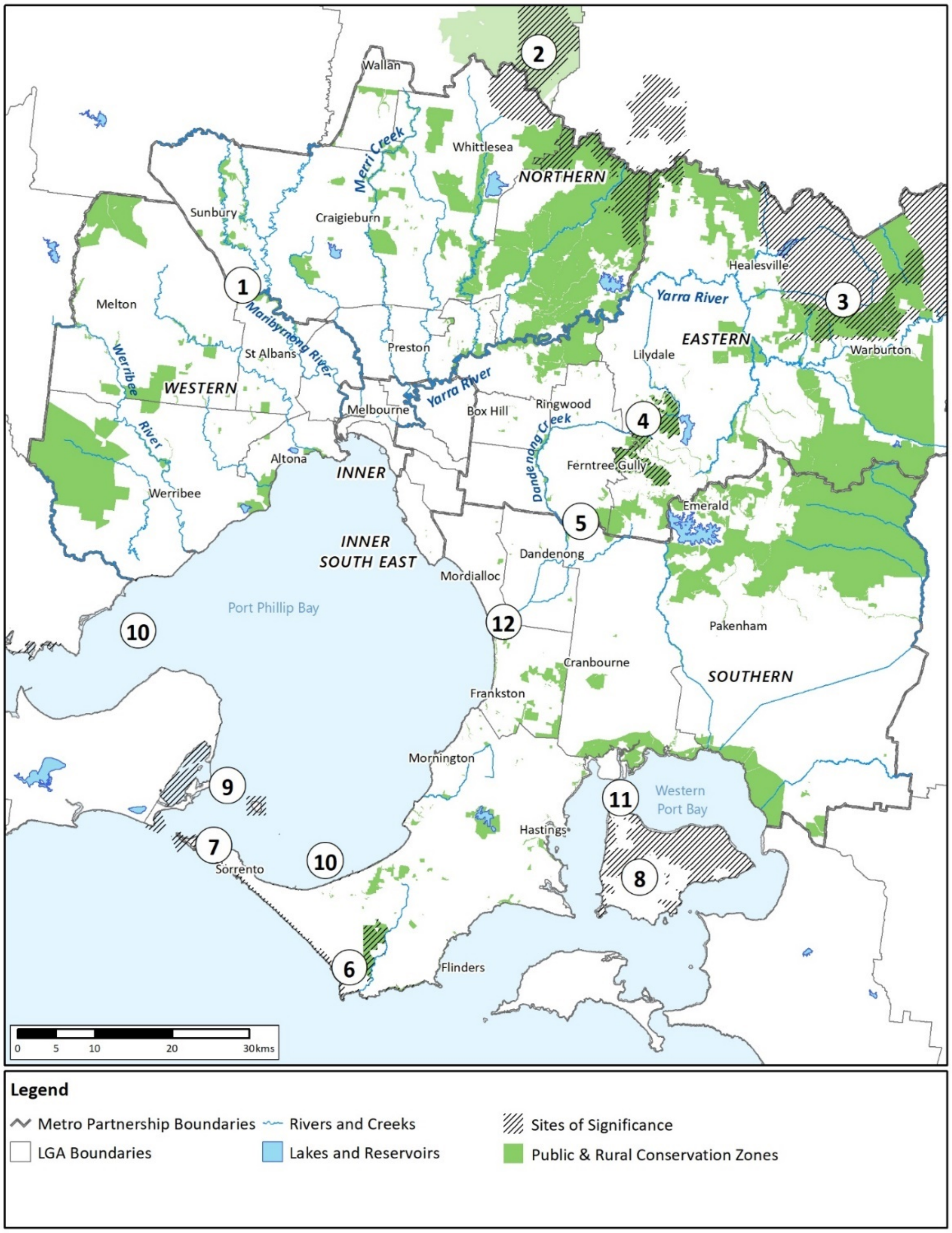


Figure 3. Map of the Living Melbourne study area showing Sites of Significance related to biodiversity. 1) Organ Pipes National Park, 2) Kinglake National Park, 3) Yarra Ranges National Park, 4) Dandenong Ranges National Park, 5) Churchill National Park, 6) Mornington Peninsula National Park, 7) Point Nepean National Park, 8) French Island National Park, 9) Port Phillip Heads Marine National Park, 10) Port Phillip Coastal Reserve, 11) Western Port Coastal Reserve, 12) Edithvale-Seaford Wetlands. (Data Source: Copyright © The State of Victoria, Department of Environment, Land, Water & Planning 2019)

2.6 The influence of the abundance, composition and structure of the urban forest on biodiversity in Metropolitan Melbourne

Urban wildlife can be categorised according to its ability to tolerate or use novel resources found in urban areas. One widely-used categorisation has identified species as urban avoiders, urban adapters or urban exploiters (McKinney, 2008), (McKinney & Lockwood, 1999). Wildlife responds to the resources available to it, and the urban forest (broadly defined to encompass the understorey, midstorey and overstorey that grows in parks, streets and residential yards) is the primary habitat for native wildlife in many cities and towns. The ecological and behavioural traits of a species are often used to predict and describe its response to urbanisation, and many studies explore the role of urban diet, movement capabilities, reproductive output and numerous other factors as explanatory variables. Conservation actions in many regions focus on restoring indigenous or native vegetation systems and the biodiversity that they support. However, urban areas can also support novel ecosystems that have no equivalent in the natural world (Hobbs, et al., 2009), (Kowarik, 2011), and non-native species of plants and animals often play important roles in the functioning of these systems and the services they provide for people and biodiversity. Consequently, the conservation of biodiversity in urban landscapes must acknowledge the role of non-native species, particularly for the resources they provide to other species of wildlife (shelter and food), the ecosystem service they may provide for people (e.g. shading and cooling), and the connection to nature that is so important for the health and well-being of residents (Shanahan, et al., 2015).

The abundance, structure and composition of all layers of the urban forest have a significant influence on the diversity and abundance of wildlife in urban landscapes. Virtually every study ever conducted on urban wildlife – from invertebrates through to birds, mammals, frogs and reptiles – has variously identified that these three components of urban forest affect habitat suitability and play an enormous role in shaping the biodiversity in cities and towns. The remainder of this section outlines how each of these three habitat components has been shown to influence biodiversity. While treated separately here, all three are closely interrelated. Abundance may be of limited value without the right structure and composition: an extensive forest cover within a landscape has little worth for wildlife if it comprises a monoculture of an introduced tree species that provides few resources.

The extent ('abundance') of the area of urban forest is the primary measure of habitat available for wildlife species. For example, trees provide some insectivorous bats with essential roosting opportunities (hollows, peeling bark) and support insects that the bats feed on. Consequently, it is not surprising that a recent study in northern Melbourne found a statistically significant positive relationship between the percentage of tree cover and the activity of insectivorous bats (Caryl, et al., 2014). Numerous other studies in Australia have similarly found that urban tree cover is an important driver of bat diversity, especially for species which typically become less abundant as urbanisation intensifies (Luck, et al., 2013), (Threlfall, et al., 2017), (Threlfall, et al., 2011). A recent study in Melbourne concluded that at least 20% of native forest cover is required to provide positive conservation outcomes for many species of insectivorous bats (Caryl, et al., 2015). Not only is the amount of landscape-level tree cover in the surrounding area an important driver of animal biodiversity, but the size of the patch itself also matters. Numerous taxonomic groups in Melbourne respond positively to area of native vegetation, including birds (Fitzsimons, et al., 2011), (Palmer, et al., 2008) and frogs (Hamer & Parris, 2011). However, not all 'native' forest is equally suitable as habitat for native wildlife, making forest abundance alone an unreliable predictor for faunal diversity. An enlightening study of insectivorous bats in Sydney found that forest on nutrient-rich geology was a frequent predictor of bat activity, while the amount of forest on poorer soils was a less reliable predictor (Threlfall, et al., 2012).

Habitat 'structure' refers to the structural attributes or elements provided by the biotic and abiotic components of the ecosystem. Biotic components include vegetation layers (ground layer, mid-storey shrubs and overstorey or canopy) and vegetation attributes (tree hollows, peeling bark, flowers), and abiotic attributes include rocks for basking, cracks, and soil hollows for shelter. A complex urban forest that maximises the number and types of structural elements also supports the most biodiversity (Müller, et al., 2018). Large trees, with a range of hollow types and sizes, extensive flowering and peeling bark are critically important in Australian urban areas for a range of faunal groups (Le Roux, et al., 2014), (Stagoll, et al., 2012).

The 'composition' of the urban forest refers to the species richness of the vegetation. Species richness is important because native wildlife is keyed into the resources that the native vegetation provides and the time when those resources are available. Species richness of native birds in 72 different neighbourhoods across 18 regional towns in south eastern Australia was strongly positively related to the abundance of nectar-rich plants, while interestingly, the density of exotic birds was lower in the same neighbourhoods (Luck, et al., 2012). A similar result was found in Melbourne, where parks and streets that support native vegetation have a greater richness and abundance of native bird species than new streets or streets with non-native trees (White, et al., 2005). As these streetscapes became increasingly dominated by exotic trees, White et al. (2005) (White, et al., 2005) also observed a reduction in the occurrence of insectivorous and nectarivorous birds that rely on native vegetation for both shelter and food. A study of birds, bats, bugs, bees and beetles in greenspaces of south east Melbourne similarly found a reduction in species richness of many groups where the composition of the urban forest comprised a greater cover of exotic plants (Threlfall, et al., 2017).

Melbourne's fauna is dynamic, and changes in species presence and abundance are largely the result of changes to the extent, structure, and composition of habitat over time. Other factors, such as habitat loss and global climate change at landscape, national or global-scales also contribute. One species that has obviously responded to change is the grey-headed flying-fox *Pteropus poliocephalus*, which prior to the mid-1980s was only an occasional seasonal visitor to Melbourne (van der Ree, et al., 2006). In 1986, a dozen animals stayed in the Royal Botanic Gardens Melbourne over winter and established Melbourne's first permanently occupied colony of flying-foxes (van der Ree, et al., 2006). There are several likely reasons for the permanent occupation of this southern reach of the bats' range. Principal among these reasons is the improved availability of food such as nectar, pollen and fruit in the urban forest due to the increase from 13 suitable plant species prior to European settlement to more than 100 species of food-yielding trees and shrubs with the addition of urban plantings (Williams, et al., 2006). Thanks to the diversity and irrigation of the urban forest, food is now reliably available year-round. The urban heat island effect also means that Melbourne is now warmer than it used to be (Parris & Hazell, 2005) and therefore climatically more like the more northern parts of the bats' range. Meanwhile, habitat loss elsewhere within the grey-headed flying fox's range has also undoubtedly contributed to its increased use of urban landscapes nationally. Rainbow lorikeets, *Trichoglossus haematodus,* have similarly expanded their range and colonised Melbourne as a result of environmental changes (Loyn & Menkhorst, 2011).

2.7 Urban densification and vegetation loss

Global debate persists about whether future urbanisation should focus on 'land-sparing' or 'land-sharing' growth strategies to balance residential demand and conservation outcomes (Lin & Fuller, 2013). Land-sparing concentrates urban development into certain areas and sets aside other land for the conservation of biodiversity, while land-sharing spreads low-intensity development over larger areas, with people and other biodiversity sharing this space (Caryl, et al., 2015). Regardless of the style of development adopted, it is important to note that in many cases urban growth of any type will reduce species diversity, including for faunal groups such as birds (Sushinsky, et al., 2013) and bats (Caryl, et al., 2015). However, Sushinsky et al. (2013) (Sushinsky, et al., 2013) noted that compact development slows these reductions at a city scale provided that large green spaces are left intact, and that urban sprawl and low-density development benefit non-native species. Melbourne's current strategy of in-fill development in existing suburbs, which applies a largely unplanned and ad hoc approach, will likely result in reductions in biodiversity because no dedicated areas for conservation are simultaneously being set aside. Furthermore, increased urban density not only reduces backyard size and opportunities for conservation, it also reduces the ability for people to connect with nature at home.

2.8 Biodiversity conservation and connecting with nature

A recent and rapidly accumulating body of evidence demonstrates that experiencing nature in cities is critical to the health and well-being of the community (Shanahan, et al., 2015), (Shwartz, et al., 2014). Unfortunately, one of the most effective approaches to biodiversity conservation for many species is to increase the density of development and protect and manage other areas primarily for conservation. While this approach can maintain community access to public open space (provided such open space is available), it means that backyards become smaller and limit opportunities for people to experience nature at their front door. In a context of rapid urbanisation, biodiversity conservation in towns and cities plays a significant role in minimising both the extinction of species and maintaining the human experience of native plants and wildlife. Although parks and reserves currently remain the focus for conserving urban nature, private gardens offer an extensive and undervalued resource for enhancing urban biodiversity (Mumaw & Bekessy, 2017). Gardens can be significant habitats in their own right, and can also improve connectivity by functioning as corridors or enlarging the size of other urban habitats. It is therefore imperative that gardens are not viewed at the individual scale, but instead managed collectively with other gardens and public open spaces as interconnected networks of green spaces across the urban landscape. Currently, the ideal size or configuration of these garden patches remains unknown, and quantifying the structure and functioning of all green spaces using landscape ecology theory and tools will further our understanding of residential ecosystems (Goddard, et al., In proof).

2.9 Connectivity

Connectivity, and the ability of plants and animals to move within or among patches of habitat, is critical for conservation because many individual patches are too small and widely dispersed to support viable populations (Crooks & Sanjayan, 2006). The movement of biota in their natural ranges occurs at spatial and temporal scales ranging from daily activities to annual migrations and once-in-a-lifetime dispersal events. Connectivity is equally import in urban landscapes, yet we know relatively little about. The urban forest plays a significant role in promoting movement in cities and towns by providing habitat as a 'permeable matrix' or green corridors. For many highly mobile urban adapter species such as the rainbow lorikeets and grey-headed flying-foxes mentioned earlier, the entire urban forest provides habitat they can utilise (Shukuroglou & McCarthy, 2006), (Williams, et al., 2006). For other species, such as the Sugar Glider, *Petaurus breviceps*, the bushland reserves of the urban forest provide critical habitat, while adjacent residential yards add connectivity and foraging opportunities (Caryl, et al., 2013). Yet other species rely on urban forest biodiversity corridors as the only safe movement path across the urban matrix.

2.10 Thresholds and urban conservation

The process of defining vegetation thresholds (the absolute minimum required to maintain species richness and diversity) and habitat attributes (e.g. tree cover, percentage of native versus exotic plant species, amount of understorey, and abundance of specific habitat elements such as tree hollows) in urban landscapes, and their importance to the persistence of particular native species, is still in its infancy. Very little empirical research has been conducted in metropolitan areas to date, with Threlfall et al. (2017) (Threlfall, et al., 2017) being an exception). Numerous modelling and empirical field studies in rural and natural landscapes have consistently identified between 10% and 30% of native vegetation cover as meaningful thresholds; below these levels, significant and alarming reductions in species richness are observed (Estavillo, et al., 2013), (Radford & Bennett, 2004), (Radford, et al., 2005). However, there is still significant debate in the scientific literature on the meaning and relevance of these thresholds (Lindenmayer & Luck, 2005), with arguments focusing on:

- The extinction debt – that many living species may already be functionally extinct due to historic clearing, thus implying the threshold will be significantly higher than those reported in the literature
- Extinction as a species-specific response that varies according to each species' resilience and/or utilisation of the matrix, and thus a threshold for one species may be substantially higher or lower than for another species.
- Threshold-responses to native vegetation cover being only part of the story, as the responses of species to the threats and processes within the cleared landscape are also important
- The potential for thresholds to have perverse outcomes and represent targets to which clearing is acceptable, rather than minimum levels to be avoided.

While the debate about these points continues, general precautionary recommendations such as 'maximise' tree cover and 'reduce threats as much as possible' remain the default in the urban ecology literature. But, while intuitively helpful, what urban planners really need are clear targets to guide and inform decision-making about how much urban native vegetation must be preserved. The most relevant thresholds in the urban ecology literature are those identified by Threlfall et al. (2017), who surveyed bugs, bats, beetles and birds on 13 golf courses, 13 urban parks and in 13 residential neighbourhoods in south-east Melbourne (Threlfall, et al., 2017). The researchers observed uniformly positive effects of the 'volume of understorey vegetation' and 'percentage of native vegetation' on the richness of the five taxonomic groups, but significant variability in the occurrence of different species. For example, the site occupancy of bats, native birds, beetles and bugs was 30% to 120% higher as the understorey volume increased from 10% to 30%, and 10% to 140% higher as native vegetation cover increased from 10% to 30% (Threlfall, et al., 2017). These results suggest that thresholds *do* exist (and appear to be around 30% for understorey volume and up to 40% to 50% native vegetation cover), but with significant variability among species. Further research is needed to determine whether these thresholds are reliable and repeatable across different parts of Melbourne and across different cities, and the degree to which all species will be protected by setting thresholds to meet the needs of the most sensitive species. In the meantime, these findings support a general philosophy of 'more is better'.

2.11 General Principles for Conserving Urban Biodiversity

While a sound understanding of the ecological and biodiversity context of an area is important, it is usually only the first step in protecting and enhancing biodiversity in a region. When it comes to planning for conserving biodiversity in urban areas, Parris et al. (2018) (Parris, et al., 2018) identified seven key principles that should be addressed:

1. Protection. The protection of existing ecological assets is essential for maintaining biodiversity in urban environments (McKinney, 2002), and involves legislative and planning instruments as well

as on-ground actions to ensure that the extent and quality of the asset is maintained into the future.

2. Connectivity. Plants, animals and other organisms require opportunities to move safely through the landscape to meet their daily needs and to maintain the viability of larger metapopulations (Crooks & Sanjayan, 2006). As different organisms have different movement capabilities, connectivity must be considered at multiple spatial scales and at different height levels. For example, connectivity at the level of the tree canopy can be beneficial for canopy dwelling species but is unlikely to provide the same degree of connectivity for ground dwelling animals.
3. Construction. Urban landscapes are intensively managed by people and constantly undergo periods of construction and renewal. These activities provide opportunities to insert additional habitat into the landscape. Ensuring that habitat features maintain structural diversity across space and time, and that there is access to additional resources such as food and water, is a third essential element of supporting urban biodiversity.
4. Cycles. Maintaining natural reproduction and nutrient cycles is essential for maintaining healthy and viable populations of biodiversity.
5. Interactions. Species do not exist in isolation. Individuals interact within a species, as well as with other species, via competition for resources or beneficial interactions such as pollination or seed dispersal. These interactions can be interrupted in urban landscapes, potentially leading to overabundant populations or local extinctions. Therefore, anticipating how changes in urban landscapes are likely to transform interactions between species allows pre-emptive action to reduce any negative impacts.
6. Benevolence. Urban environments can be quite harsh – the urban heat island can increase temperatures and reduce moisture availability, artificial light at night can disrupt circadian rhythms, and anthropogenic noise generated by human activities can interfere with a species' ability to communicate. Planning, designing and building cities that reduce these impacts will increase the number of species that are able to persist into the future.
7. Novelty. Cities and towns contain an array of new forms of ecosystems that do not have a historical precedent yet offer new forms of habitat for species (Hobbs, et al., 2009), (Kowarik, 2011). Recognising the contributions of novel habitats allows for a wider range of ecological assets to be identified within our urban landscapes.

Metropolitan Melbourne supports a highly diverse and species-rich natural environment. While we have many positive measures in place to protect and enhance this biodiversity into the future, there is little time for complacency. *Living Melbourne* is a timely and invaluable opportunity to achieve outcomes for people and biodiversity:

> ‘In managing urban biodiversity, we are seeking to preserve Australia’s unique plants, animals and ecosystems for the multiple benefits they bring to people. The preservation element relates to a nature-focussed conservation goal, but the multiple benefits are more closely aligned with a human-centric ecosystem services outcome. While these things are related, they are not the same. If we only pay attention to one, we may produce a system where people win, or where nature wins, whereas really what we need to strive for is a win-win situation, where people and biodiversity both benefit. We need to explore what an ecologically-designed landscape might look like.’ (Hahs, 2017)

3 Benefits of the urban forest

3.1 Introduction

This chapter discusses the ecosystem services and benefits that the urban forest brings to metropolitan Melbourne's community.

3.2 What is an ecosystem service?

Ecosystem functions are the energy and nutrient processes that take place in the animal and plant kingdoms. Examples include plant growth, decomposition of organic matter, seed dispersal, and animal reproduction. Ecosystem functions that directly increase an individual's well-being are called ecosystem services (McDonald, 2015). Ecosystem services can be defined as 'the components of nature, directly enjoyed, consumed, or used to yield human well-being.' (Boyd & Banzhaf, 2006, p. 619)

Typical urban ecosystem services provided by plants and trees include:

- maintaining or improving water quality in water catchments
- assisting the treatment of urban stormwater
- lowering water tables, which reduces the risk of salinity
- flood mitigation by slowing runoff
- reducing coastal erosion and flooding through natural coastal habitats like wetlands, shellfish reefs and mangroves
- sequestering carbon
- capturing airborne particulates, which improves air quality
- lowering air temperatures via transpiration
- reducing surface temperatures through shading
- improving urban amenity and therefore community pride of place
- proving cool green space for active and passive recreation
- supporting our mental health and feeling of well-being

Table 8 provides a short list of ecosystem services most relevant to cities. (McDonald, 2015)

Table 8 Ecosystem service of greatest relevance to cities, classified according to the Millenium Ecosystem assessment, the category of economic good they represent, and spatial scle at which they operate

Ecosystem service	Economic category	Spatial scale
Provisioning services		
Agriculture (crops, livestock, aquaculture, etc.)	Private good	Regional to global
Water (quantity)	Private good	100 km^2 – upstream source watershed
Cultural services		
Aesthetic benefits	Public or common good	10 km^2 – area of daily travel by urbanites
Recreation and tourism	Public or common good	10 km^2 – area of daily travel by urbanites
Physical health	Public or common good	10 km^2 – area of daily travel by urbanites
Mental health	Public or common good	10 km^2 – area of daily travel by urbanites
Spiritual value or sense of space	Public or common good	Varies – often local, but can be up to global
Biodiversity	Public or common good	Varies – global for existence value, local for direct interaction
Regulating services		
Drinking water protection (water quality)	Public good	100 km^2 – upstream source watershed
Stormwater mitigation	Public good	100 m^2 – downstream stormwater system
Mitigating flood risk	Public good	100 km^2 – downstream flood-prone areas
Coastal protection	Public good	10 km^2 – coastal zone
Air purification (particulates, ozone)	Public good	100 km^2 – regional airshed
Shade and heatwave mitigation	Public good	<100 m – varies with the solar angle

3.3 Why are ecosystem services significant?

A substantial body of literature recognises the benefits of a healthy urban forest. It can provide -

- Physical health benefits by encouraging physical activity, thus lowering obesity levels and reducing the incidence of some diseases (e.g. chronic heart disease). It is also beneficial for healing and pain relief.
- Mental health and well-being by reducing stress. Stress reduction produces a range of positive outcomes, including to concentration and memory, impulse inhibition, aggression, stress relief, mood, self-esteem, childhood developmental behaviours, depression, cancer, and Attention deficit hyperactivity disorder (ADHD) behaviours in children. People prefer vegetated urban areas to non-vegetated urban landscapes, and their choices bring about the resultant health and well-being values.
- Social cohesion by providing a welcoming shared space, increasing community and neighbourhood connection, and reducing levels of fear and crime.

- Biodiversity and native species conservation through benefits for species richness, and habitat for native and threatened species.
- Ecosystem services via cooling and improved air quality. Vegetation generally, and large trees in particular, reduce urban heat both at street and neighbourhood levels. Urban vegetation, and especially trees, capture and filter air pollutants, including ground-level ozone, sulphur dioxide, nitrogen oxides and particulate matter (Kendal, et al., 2016).

Ives' research concluded that we should avoid a 'one size fits all' approach to urban forest planning (Ives, et al., 2017). His research revealed a complex picture of how different values were assigned to green spaces, but also that different value types are compatible with each other (for example, 'native plants and animals' and 'health/therapeutic' values). Ives suggested that the findings "present an opportunity for management agencies to maximise biodiversity across the whole landscape rather than focussing exclusively on formal nature protection areas, since residents value nature in all types of green spaces."

3.4 How does an urban forest mitigate heat?

3.4.1 A global view

A critical, health-related benefit associated with the urban forest is heat mitigation. Humans have adapted to living in a specific temperature range, and extreme cold or heat is problematic for human health and society. The focus of this section is on temperatures above the human comfort zone as these are the predicted result of climate change.

Average maximum summer air temperatures in cities globally vary greatly, from less than 23°C for some far northern European cities to more than 36°C (97°F) for some sub-Saharan African and Middle Eastern cities. The replacement of shade-bearing and water permeable vegetation with impermeable urban infrastructure has resulted in city environments becoming warmer than their rural surrounds, both in air and surface temperatures (Coutts, et al., 2012), (Filho, et al., 2017). Compared to the countryside, cities have extensive areas of impervious dark surfaces that can absorb, store, and slowly release substantial amounts of heat. Heat from these surfaces may take many hours to dissipate entirely. Compared with moist and shaded environments, a built-up city with one million or more people can have average air temperature increases of 1°C to 3°C during the day and up to 12°C during the night, while city surface temperatures during the day can be 10°C to 32°C higher than air temperatures (EPA, n.d.). This is known as the 'urban heat island effect' and results from:

- the generation of waste heat from concentrated anthropogenic activities (e.g. cars, heating, cooling)
- the concentration of materials that are effective insulators or absorbers of urban heat
- the geometry (compactness) and height of cities, which exacerbate heat retention, and
- increased impermeable surfaces, and the subsequent reduction in soil moisture and soil surface area for evaporative cooling

Approaches to reducing the urban heat island effect include the use of 'green' roofs, light rather than dark surfaces, and the establishment of canopy cover from urban forests. The aim is to reduce air temperatures to maintain public health and well-being.

3.4.2 Excess heat and health impacts

Exposure to high temperatures can adversely affect the health of urban residents. A set of conditions called 'heat injuries' are directly attributable to acute, short-term exposure to heat. Most commonly, acute heat exposure, combined with dehydration, can lead to heat cramps and fainting. Continued exposure can lead to heat exhaustion, which combines the above symptoms with a headache, feelings of dizziness and confusion, pale skin, and profuse sweating. Exposure to extremely high temperatures can lead to heat stroke, and untreated heat stroke can quickly cause damage to the brain, heart, kidneys, and muscles, and in some cases coma or death (Ezzati, et al., 2004).

Epidemiological studies show a significant rise in overall mortality and morbidity during periods of high temperature (McMichael, et al., 2004). Temperatures do not have to be extreme to cause an increase in overall mortality – just above average summer temperatures are enough to have a dramatic impact. Increased mortality occurs mainly because high temperatures are risk factors for other diseases such as heart attack and stroke, particularly in elderly populations. High temperatures are considered to be the weather-related disaster that causes the most mortality globally, killing on average 12,000 people annually in 2004 (Ezzati, et al., 2004); the current global average mortality is likely to be higher. Climate change is dramatically increasing global temperatures, and eight of the ten warmest years in the last century have occurred since this 2004 study was published (NASA/GISS, 2018).

Heat-related mortality is highly episodic and concentrated during particular heat events. Table 9 lists a number of major heatwaves and their estimated health effects. One of the best-studied heatwaves occurred in Europe in 2003 and killed up to 70,000 people (Robine, et al., 2003). In August 2003, parts of France recorded daily temperatures that were 8°C higher than usual (NASA, 2003), and subsequent analysis found that mortality rates in Paris were 142% higher than usual in that month. Microclimate – the temperature of neighbourhoods – was a strong predictor of death (Vandentorren, et al., 2004), with warmer Parisian neighbourhoods more likely to suffer fatalities.

Table 9 Selected major heatwave events and their resulting mortality impacts based on scientific literature

Location	Year	Mortality
United States (eastern)	1901	9,500 killed
United States (Midwest)	1980	1,700 killed
Greece (Athens)	1987	> 1,000 killed
United States (Chicago)	1995	739 killed
Europe	2003	70,000 killed
India (Andhra Pradesh and Telangana)	2015	> 2,200 killed

Other global studies have constructed curves that relate all-cause mortality to the excess temperature above a safe baseline, with each 1°C increase being associated with a 3.0% to 5.5% increase in all-cause mortality, and a 1.1% to 2.6% increase in cardiovascular mortality (Ezzati, et al., 2004). Another recent report by the World Health Organization (Hales, et al., 2014) used functional relationships (Honda, et al., 2014), where, for instance, a 10°C increase above baseline causes an approximate 18% increase in all-cause mortality, and a 20°C increase above baseline increases all-cause mortality by roughly 50%. While the safe baselines used in the various studies differ, during the European heatwave of 2003, some cities were approximately 15°C to 20°C above the safe baselines.

3.4.3 Vulnerability to heat in Australia

Periods of extreme heat pose a threat to the elderly, very young, and those who are chronically ill. A recent Australian study analysed the spatial relationships between vulnerable urban populations and extreme heat events (Loughnan, et al., 2013). The principal risk factors related to adverse health outcomes were found to be areas with intense urban heat islands, areas with higher proportions of older people, and areas with a high proportion of culturally and linguistically diverse communities. A close correlation was found between vulnerability and ambulance call-outs in Melbourne on hot summer days.

This was also reflected in the 2019 analysis of land surface temperatures that was undertaken in support of this strategy. Using a variety of Australian Bureau of Statistics indices such as the Socio-Economic Indexes for Areas (SEIFA index), which ranks areas in Australia according to relative socio-economic advantage and disadvantage, the analysis found a close correlation between hot spots in the landscape and vulnerable populations. It also identified that, in most cases, there is a greater number of hot spots where the percentage of residential rental properties is highest and where weekly household income was lower. Please refer to Chapter 7 for the detailed analysis.

Additionally, in 2017, Horticulture Innovation Australia completed a nation-wide report that provides data to help the horticulture industry and the 202020 Vision project, a national campaign to increase urban green space in Australia by 20% by 2020, to identify the priority areas for greening (Amati, et al., 2017). The principal objective was to consider how local government's greening efforts can most effectively protect community sectors that are particularly vulnerable to high temperatures but have little access to green areas due to socio-economic, health or age factors. The research highlights the vulnerability of different community sectors to a lack of canopy cover, heat stress, poor health, and challenging socio-economic circumstances. It includes detailed maps and graphs that can identify priority areas for green interventions across crucial local government areas.

The report illustrates the relationship between socio-economic indicators and urban vegetation. The project team developed an index that identifies which areas of socio-economic and health disadvantage coincide with a lack of green cover and a high incidence of heat events. Although limited by available data, the index reflects the relationship between urban heat islands and the percentage of tree canopy cover.

The report also noted that tree canopy has the most significant impact on reducing urban heat while shrubs have a lesser effect. It notes that unirrigated grassland increases percentage hot spots, possibly due to unirrigated pasture resulting in hot areas. However, within this context, it should be noted that shrubs and grasslands have other benefits and play an essential part in our urban biodiversity by providing habitat and refuge for birdlife and other fauna. Also, shrubs will assist pollution reduction as part of a road buffer with good structure (understorey and canopy) by reducing particulates such as PM2.5 and PM10 (see 3.5.2 below).

The report identified opportunities on land associated with industrial facilities, airports, large areas of railway land, significant highways and roofs as areas that could be greened to contribute to the urban forest.

3.4.4 Victorian case study – 2009 Heatwave

The 2009 Victorian Bushfires Royal Commission (2009 Victorian Bushfires Royal Commission, 2010) formed to investigate the Black Saturday bushfires (February 7, 2009) identified that these fires killed 173 people and injured another 414. The fires also claimed the lives of more than a million wild and domesticated animals and damaging 450,000 hectare of land (4,500 km^2). When a heatwave struck south-eastern Australia in the weeks before February 7, it greatly exacerbated the impact of the two previous months of already hot and dry conditions. Melbourne endured three days above 43°C, and the temperature peaked on the January 30 at 45.1°C, one of the hottest days ever recorded in the city. These temperatures, combined with extremely low levels of humidity, created tinder-dry conditions in the Victorian bush. On February 6, Premier John Brumby issued a public warning that the next day was expected to be the "worst day [for fire conditions] in the history of the state" (Anon., n.d.).

Tragic as these fires were, they were not an isolated event but formed part of an emerging trend. The preceding record-breaking heatwave between January 26 and February 1 had contributed to the deaths of 374 people. As Victoria's Chief Health Officer (Victorian Government Department of Human Services Melbourne, 2009) reported three consecutive days above 43°C and maximum temperatures were up to 15°C higher than average, the state's death toll rose 62% from the same time of the previous year. Nine hundred and eighty people died during the week compared to a weekly mean of 606 deaths for the last five years. Most of those who died (248 people) were aged 75 years or older, and 46 people were aged between 65 and 74.

3.4.5 The future of urban heat

Heatwaves will continue to be a challenge for cities in the future. Globally, more than two billion additional people are expected to live in cities by 2050 (United Nations, Department of Economic and Social Affairs, Population Division, 2015), exposing many of them to the urban heat island effect. Housing new urban dwellers will require additional land development, which in turn will potentially increase the loss of forests and natural vegetation and further contribute to urban heat islands.

Climate change will make heatwaves more frequent and intense. The Nature Conservancy's global study of 245 of the world's largest cities noted that all were forecast to expect average maximum temperatures to increase between roughly 1°C to more than 4°C above current maximums (The Nature Conservancy, 2016). The World Health Organization estimated that by 2030, annual deaths due to high temperatures could rise to almost 100,000 globally (eight times more than the current figures (Hales, et al., 2014), and by 2050, annual heat-related deaths could reach almost 250,000 (Figure 4). Reducing these anticipated deaths will depend on future efforts to reduce greenhouse gas emissions to contain climate change, and on the actions taken to prepare for, and adapt to, climate change.

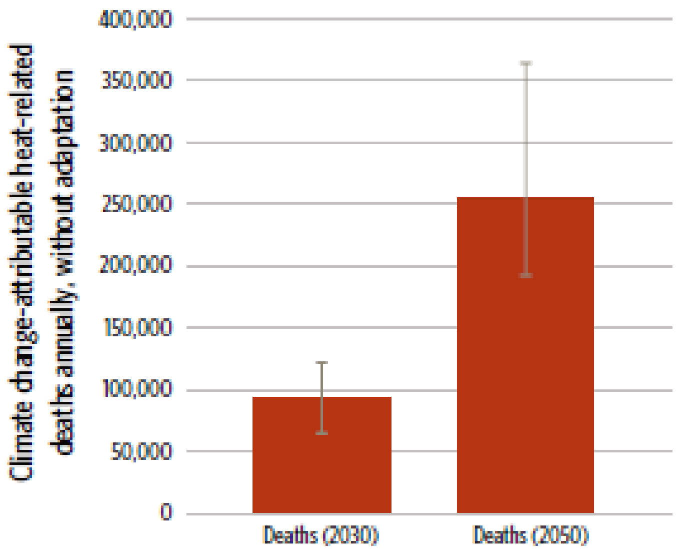


Figure 4 **Forecast of climate change's impact on deaths due to excess heat expressed as annual mortality numbers in 2030 and 2050. The WHO study looked at a range of climate scenarios, which cause a range of death (shown in error bars). Data taken from WHO (2014)**

3.4.6 Trees and temperature reduction

A tree canopy produces a cooling intensity that is defined as the degree Celsius reduction relative to the average temperature outside the patch covered by the canopy. Generally, the larger the canopy, the greater the cooling intensity. The cooler air from beneath the canopy then disperses away from the patch and slowly mixes with the adjacent hot air. The further the air moves from the canopy, the closer the temperature gets to the average temperature in the city (Figure 5).

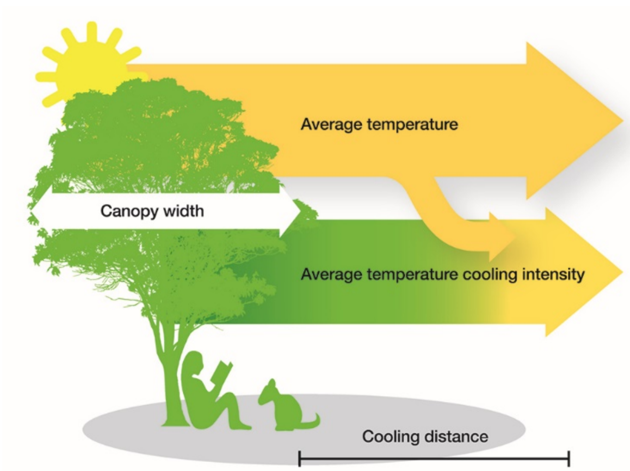


Figure. 5 **Temperature mitigation by trees (© Mackinzie Jones, Apertures)**

The cover provided by trees and other vegetation can affect cooling intensity in two ways. First, vegetative cover shades impervious surfaces and prevents the sun's rays from hitting them, thus inhibiting heat storage and subsequent release, which would contribute to the urban heat island effect. Trees that are tall enough to create a large shaded area under their canopy are more useful than short vegetation. Trees also transpire water as they grow and photosynthesize. The water absorbs surrounding warmth and is converted from liquid to water vapour, storing the energy as latent rather than sensible heat. From the perspective of mitigating extreme temperatures, this latent heat storage prevents an increase in air temperature, although the loss of water from planted trees may put a strain on the trees' water supplies (Taha, et al., 1991).

In urban areas, both the transpirative cooling (Gromke, et al., 2015) and the shading effect (Andreou, 2014) of individual trees can substantially lower maximum summer daytime air temperatures at the street and pedestrian level. However, the shading of sealed surfaces under a tree canopy has a particularly critical effect on pedestrian thermal comfort because it dramatically lowers surface temperatures (Vailshery, et al., 2013), (Sanusi, et al., 2016) and the mean radiant temperature to which pedestrians are exposed (Vailshery, et al., 2013), (Sanusi, et al., 2016), (Cohen, et al., 2012), (Taleghani, et al., 2014). Mean radiant temperature is a function of the heat fluxes (short and longwave radiation) that a body receives from surrounding surfaces (Mayer, et al., 2008), and it is the key temperature component determining human thermal comfort in summer (Mayer, et al., 2008), (Ketterer & Matzarakis, 2014), (Shashua-Bar, et al., 2011).

The intensity of the cooling effect of urban trees can vary substantially between tree species (Feyisa, et al., 2014), (Ballinas & Barradas, 2016) and tree size. This is due to differences in foliage density and leaf area index, leaf thickness, orientation and light permeability, as well as photosynthetic and water use rates. A larger, denser canopy is better - cooling intensity shows a strong positive relationship with canopy area and density (Feyisa, et al., 2014), (Chang, 2014). The summer daytime cooling effect of individual trees, street trees, or larger treed areas has been quantified in experimental studies in temperate, subtropical, and tropical regions (Bowler, et al., 2010). Cooling intensity for street trees varies from 0.4°C to 3.0°C, depending on the site and the time of day. Results from studies of urban parks reveal that cooling intensity varies from close to 0°C to 6.7°C, depending on the site, the time of day, and the distance from the park at which the measurement was taken (The Nature Conservancy, 2016).

The spatial zone – or distance – over which cooling occurs is important. The cooling effect extends into surrounding areas primarily through advection (Sugawara, et al., 2016), (Taha, et al., 1991), and its reach is a positive function of canopy area mediated by airflows and temperature gradients with the surroundings (Feyisa, et al., 2014), (Sugawara, et al., 2016). Most studies find that the maximum cooling distance of urban forest patches or partially forested parks on sunny summer days extends to approximately one park width from the park (Spronken-Smith & Oke, 1998), (Jauregui, 1991), although shorter or much longer distances are possible (Shashua-Bar, et al., 2011), (Chang, 2014). For street trees, the likely effect on temperature reduction is strongest within 30 metres of a tree.

A large amount of literature suggests trees can provide localised but meaningful reductions in temperature and should be complementary rather than a replacement to other means of reducing ambient air temperature. For example, a strategy for buildings is to plant vegetation on the roof. Plants shade the roof and prevent heat storage. Plants and soil surfaces also transpire water, increasing latent heat storage and thereby decreasing sensible heat. An attractive green roof provides many benefits beyond heat mitigation, including aesthetic beauty for the building's residents and increased property value. The main challenge is that greening vegetation is relatively expensive to install on roofs that weren't designed to support soil and plants, and the cost of retrofitting a roof can be significant.

The Low Carbon Living CRC *Guide to Urban Cooling Strategies (2017)* provides practical guidance for built environment professionals and regulatory agencies seeking to optimise development projects to moderate urban microclimates and mitigate urban heat island effects in major urban centres across a range of climates in Australia, including in Melbourne (Osmond & Sharifi, 2017). With an emphasis on the public realm, the document addresses a range of urban typologies, including the dense inner city, middle ring, and outer suburbs. Amongst cooling strategies such as permeable paving, cool roofs, built-shading and evaporative cooling, the guide addresses the use of vegetation as a cooling tool in the Australian context in some detail. It notes that "a lack of sufficient vegetation cover is a defining feature of highly developed urban areas", and "… also a major contributor to the urban heat island effect through decreased evapotranspiration in cities" (p. 19). The guide goes on to discuss the positive cooling benefits of urban vegetation, specifically:

- Street trees
- Natural turfs and grass cover
- Urban parks
- Green roofs
- Green walls

Green roofs, green walls and tree canopy are suggested as part of an 'urban cooling context-intervention matrix' with other cooling techniques for the inner city, inner suburbs and outer suburbs, and specific suburban cooling strategies are recommended for each Australian city.

Trees mitigate air temperature either by shading impervious surfaces (preventing heat storage) or by transpiring water (transferring energy to latent heat). Therefore, tree species that have a high leaf area index (defined as the ratio of leaf area to ground area under canopy) cast denser shade and are more effective at reducing temperatures. In temperate areas with hot summers but cool winters, deciduous trees may be more appropriate, as they supply shade during the hot season but allow the sun to shine through in the colder months. Trees chosen for shade plantings should be appropriate for a city's climate zone.

Relatively few studies have looked at the temperature mitigation potential of specific species of trees. One interesting study in Addis Ababa (Feyisa, et al., 2014) looked at the temperature mitigation potential of different species, with eucalyptus *(Eucalyptus* spp.*)* cooling more than cypresses *(Cupressus* spp.*)*, Grevillea spp., or acacias *(Acacia* spp.*)*. A study in Mexico City, by comparison, found that sweet gum *(Liquidambar styraciflua L.)* was significantly more effective at temperature mitigation than eucalyptus *(Eucalyptus* spp.*).* (Ballinas & Barradas, 2016)

3.5 How does an urban forest improve air quality?

3.5.1 Air pollution from particulate matter

Among the most pressing of global urban environmental challenges is air quality. In many cities, the most damaging air pollutant is particulate matter (PM), which is emitted from a variety of sources, especially the burning of agricultural residues, fuelwood, and fossil fuel (Anderson, et al., 2012). Fine particulate matter (less than 2.5 micrograms (µg) in diameter, also known as PM2.5) can be inhaled deep into the lungs and is estimated to cause 3.2 million deaths per year (around 4% of the global burden of disease) (Figure 6), primarily from cerebrovascular disease (e.g. stroke) and ischemic heart disease (e.g. heart attack) (Anderson, et al., 2012), (WHO, 2005). PM2.5 exposure also contributes to chronic and acute respiratory diseases, including asthma. And the problem has the potential to get worse: one study forecast that by 2050, fine particulate matter could kill 6.2 million people per year (WHO, 2005).

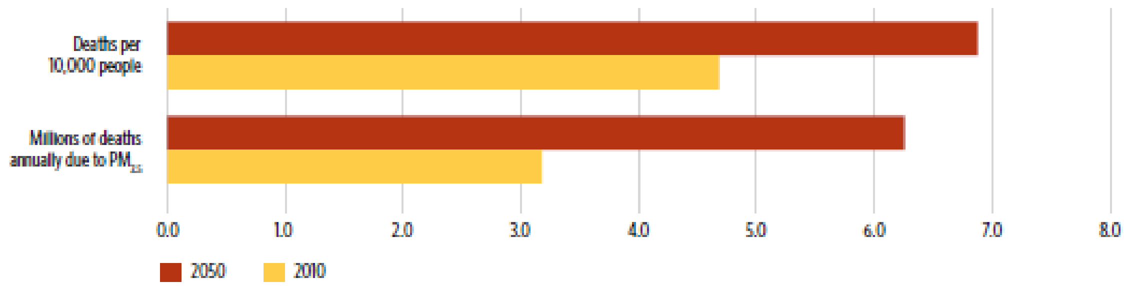


Figure 6 **Forecast global mortality from $PM_{2.5}$ in 2050 compared to 2010, expressed either as the total number of deaths, or as the number of deaths per 10,000 people. The number of people forecast to be killed will almost double (i.e. increase by 100 %). Some of that increase is due to population growth alone. The number of deaths per 10,000 people, however, is still expected to go up by roughly 50 %, primarily due to an increase in $PM_{2.5}$ concentrations in cities in the developing world. Data taken from (The Nature Conservancy, 2016)**

3.5.2 Trees and Particulate matter

Conceptually, there are three processes that relate to PM concentration and trees (Figure 7).

1. Incoming airflow carries a certain concentration of PM (µg/m³).
2. Passing of the incoming airflow through the canopy removes a fraction of the PM. Note that some fraction of the incoming airflow is deflected by the canopy, which can result in locally higher concentrations of PM upwind of a tree. Proper design and location of plantings can ensure that this local concentration does not occur in places where it might put people at risk.
3. Cleaner air exits the canopy and continues moving downwind. Over some distance, this cleaner air mixes with other air that didn't pass through the canopy (re-dilution), and the concentration of PM approaches the average concentration for the region.

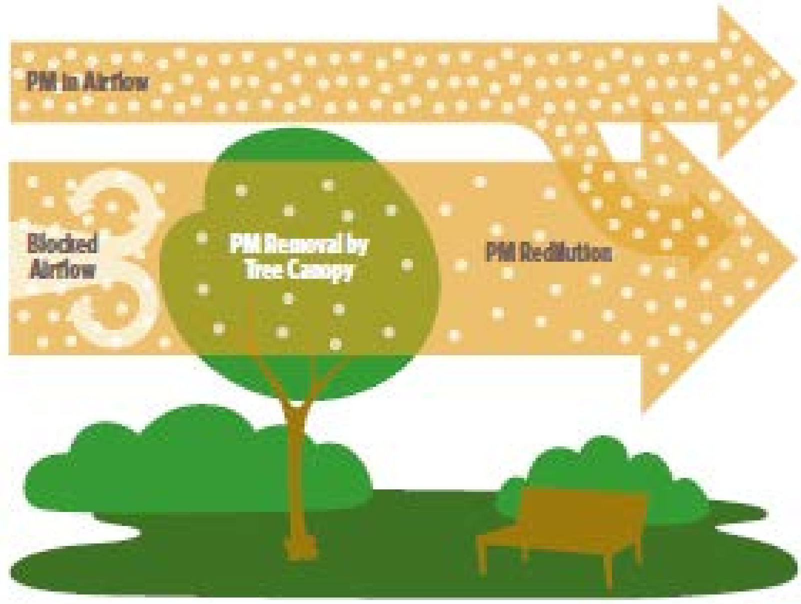


Figure 7 Diagram of particulate matter (PM) removal by trees (© Mackinzie Jones, Apertures)

3.5.3 Particulate matter removal by tree canopy

Particulate matter is removed by plants through a process known as dry deposition. During dry deposition, particles in the atmosphere deposit themselves on a surface, decreasing the atmospheric concentration of PM (Litschke & Kuttler, 2008). Much of the fine fraction (PM2.5) becomes permanently incorporated into leaf wax or cuticle, while a portion of the coarse fraction is resuspended in the air as a function of wind speed (Nowak, et al., 2013), (Nicholson, 1988). The remainder of the coarse fraction is eventually washed off by precipitation (Matzka & Maher, 1999).

Research findings differ on how much PM tree canopies are able to remove. One key parameter is the concentration of the pollutant: At higher atmospheric concentrations of PM, the rate of dry deposition or absorption is greater. Another parameter is the leaf area: more leaf area offers more surface area on which dry deposition or absorption can take place. Finally, the amount of mixing of the atmosphere matters as well, with better mixing associated with more canopy removal of PM.

The current literature suggests that tree planting and other vegetative screens have primarily local PM benefits. Most reductions in PM concentrations occur within 30 metres of the vegetation, with very little reduction in concentration beyond 300 metres. This horizontal distance depends on wind speed (advection) and turbulent mixing (diffusion) within the urban canopy layer (approximately up to roof height), which are strongly influenced by urban surface morphology (Fisher, et al., 2006), (Carpentieri, 2013). Maximum benefit from plantings is therefore derived where trees are planted at the appropriate density and close to large numbers of people. Within this impacted zone, significant reductions in PM are possible. One study found that a row of roadside street trees lowered indoor PM10 concentrations in houses along the street by 50% (Maher, et al., 2013). Another study found that a single tree lowered PM10 concentrations behind it by 15% (Mitchell & Maher, 2009), and a third study (Bealey, et al., 2007) found that PM concentrations could be reduced by 20%.

The *Green for Good: Assessing the Health Returns of Green Investment* project assessed the impact of green infrastructure on the health of children in the City of Louisville, Kentucky, USA. A screen of mature trees and shrubs was planted along the busy road in front of a school, and urine and blood tests were taken from the children and staff three weeks before and three weeks after the screen was installed. The results showed that, under certain conditions, the green-wall bio-filter reduced particulate pollution by 60%. Blood tests taken after the plantings showed that higher levels of circulating angiogenic cells (CACs) in both students and staff. These cells keep blood vessels healthy, and higher levels of CACs reduce the risk of heart disease. In children, the levels of immune cells were lower after planting, suggesting that children may be more sensitive to changes in their environment than adults (Louisville Metro Government, 2017). A large body of literature suggests that trees can provide localised but meaningful reductions in PM but should complement rather than a replace other particulate reducing strategies.

3.5.4 Characteristics of tree species

Tree plantings often need to address multiple objectives, including improving biodiversity, adding aesthetic beauty, and being easy to maintain, disease resistant, and hardy in the local climate. Places in which to plant urban trees vary from crowded urban streets to more natural habitat and open space. In addition to the multitude of goals and potential places for trees, species selection or planting strategies must also be tuned to the needs of the local community. However, tree plantings should also incorporate some principles for PM removal and temperature mitigation. Tree leaves remove PM through dry deposition, and tree species that have a larger leaf surface area will generally remove more PM. A large total leaf surface area can be achieved with species that have a dense canopy, or because the leaf surface is 'rough' (with lots of ridges or hair), which increases the surface area for interception (Yang, et al., 2015). An analysis of multiple tree species also that those found those with waxier surfaces generally remove more PM (Sæbø, et al., 2012).

Another consideration in choosing trees is whether a tree is deciduous or evergreen. For the purposes of PM removal, being evergreen is a plus for year-round PM removal as deciduous trees would be less effective in the winter months. A useful study lists the PM removal efficiency of the 100 most commonly planted urban trees globally (Yang, et al., 2015). Species that score high on PM removal efficiency include such common temperate species as eastern red cedar *(Juniperus virginiana L.)*, red maple *(Acer rubrum L.)*, American elm *(Ulmus americana L.)*, and white poplar *(Populus alba L.)*. Some common species that score poorly for PM removal include chokecherry *(Prunus virginiana L.)*, flowering dogwood *(Cornus florida L.)*, and white ash *(Fraxinus americana L.)*. To date, few data are available for Australian urban trees.

Research for *Living Melbourne* found that there is a limited understanding of the relative ability of Australian tree species to capture airborne particulates, in particular PM2.5 particulates. Further research could compare the relative merits of Australian species with northern hemisphere species. Literature identified to date incudes:

- Yang et al. (2015): this provides a ranked list of the 100 most common street trees planted world-wide and their suitability to reduce PM2.5 particulates. No Australian species were listed. It noted that evergreens captured more particulates per annum and that conifers were very efficient.
- Freer Smith et al. (2003) compared particulate pollution (PM10) capture by semi-arid species including *Eucalyptus globulus* (Tasmanian Blue Gum) against five species used widely in woodland of urban and peri-urban areas of Europe. Results indicated that blue gum has low relative deposition velocity and capture efficiency for its leaves but relatively high for its stems.

- Brack (2002) placed an estimated value of airborne particulate pollution mitigation of US$1,050,000 per year on Canberra's 400,000 public trees.

3.5.5 Types of plantings

Major roads can be a significant source of air and PM pollution from vehicles. Tree planting along such roads must be done with some care. Trees reduce PM loading through dry deposition, but they can also inhibit air circulation, trapping pollution in and under the canopy. In some cases, this can be an advantage. For instance, a dense line of trees or shrubs can trap dirty air over a highway, preventing it from moving laterally into other parts of the city. However, if trees are trapping dirty air on major residential roads, it can inadvertently increase people's exposure to particulate matter. Care should be taken when planting trees near major emission sources, and consideration given to the tree species to be planted, their eventual canopy volume, the geometry of nearby buildings and other features that block wind flow, and wind speed and direction (Pugh, et al., 2012). One study suggested that along major roads, single roadside tree lines should be planted of a species with high PM removal capacity, with enough spacing between tree canopies to allow wind flow between trees (Maher, et al., 2013).

Many roads, however, are not major sources of air pollution since they have relatively little traffic (e.g. residential streets with urban residents). Due to the lower traffic levels on these streets, there is less risk of trapping dirty air by blocking wind circulation and greater interest in maximising tree cover for shade. Greater leaf area will help with shade and also allow more PM removal through dry deposition. Since these street trees will be right next to homes and businesses, they should be aesthetically pleasing, hardy enough to withstand an urban environment, and meet the other needs of the local community.

As the ability of trees to reduce PM and temperature is relatively localised, trees that are planted in the middle of urban green parks or other open space have relatively less importance for making air healthier, simply because few people live or work within a few hundred meters of these trees. Thus, while the ability of particular tree species to reduce temperature or PM should be considered when selecting the list of species to plant, it is likely these characteristics will be selected from a set of factors that are important in a park setting (e.g. aesthetic beauty, wildlife value). In these settings, the value of parks and open space for recreation and socialisation is likely one of the most important ecosystem services, and the ability of trees to reduce PM and temperature may be of secondary importance.

3.5.6 Return on investment for particulate matter and heat reduction

Return on Investment of tree planting for air temperature mitigation varies significantly among neighbourhoods. The ideal high Return-on-Investment neighbourhood has a high population density (or a concentration of sensitive populations), leading to larger number of people benefiting from heat reduction by trees. Higher-population density neighbourhoods generally score higher, simply because any reduction in ambient air temperature benefits a larger group of residents.

Sensitive sites, such as schools, hospitals, retirement villages, kindergatens and aged-care facilities should also be a focus. Because populations (young children or the elderly) that use these sites are most likely to suffer negative health effects from air pollution or high temperature, it makes sense to concentrate tree planting around these facilities. Young children, for instance, are especially sensitive to asthma, while the elderly are at increased risk of negative health impacts from exposure to extreme heat (The Nature Conservancy, 2016).

3.6 Physical, mental, social and spiritual health and wellbeing

3.6.1 Intrinsic health benefits of the urban forest

This section has drawn significantly from Park Victoria's Healthy Parks, Healthy People study (Townsend, et al., 2015). Parks Victoria identifies four major categories of human health:

- Physical
- Mental
- Social
- Spiritual

The World Health Organization's definition of health is "a state of complete physical, mental and social wellbeing, and not merely the absence of disease or infirmity." It therefore includes the concept of 'wellbeing', which is defined by the US Centre for Disease Control and Prevention as "a valid population outcome measure beyond morbidity, mortality, and economic status that tells us how people perceive their life is going from their own perspective."

1.6.1 Physical health benefits

Research evidence indicates clear links between the proximity of parks and the physical health of adult populations. For example, men living in areas with greater green spaces have lower risks of mortality from cardiovascular and respiratory diseases, while adults in urban environments who live closer to parks are likely to have a lower Body Mass Index (BMI) than those who live further away. An Australian study found that residents in neighbourhoods containing more than 20% of green space were significantly more likely both to walk and to participate in moderate to vigorous physical activities (MVPAs) on at least a weekly basis.

Promotion of active lifestyle & behaviour change

Access to natural green space not only increases levels of physical activity (thus reducing the risk of stress factors, including non-communicable diseases) and improves immune function, but also has the potential to address other stresses by providing mental health benefits and facilitating social connectedness and independence.

Research has shown that local accessible parks and outdoor spaces can facilitate active lifestyle behaviours that are modelled to children and other family members. These include choosing active transport, pet ownership, promoting pro-environmental behaviour within the family, and increasing direct participation in one's own community.

Given the importance of physical mobility in maintaining the autonomy of older adults, the value of well-maintained, safe, accessible park facilities cannot be overestimated.

Rehabilitation and recovery

In addition to the health benefits of green spaces for the general adult population, research has shown specific benefits for those undergoing rehabilitation or clinical treatment. Literature examining environments that promote physical rehabilitation in clinical populations recognises that exposure to natural green spaces supports a greater sense of wellness. Adults undergoing cancer treatment who were able to undertake rehabilitation in outdoor spaces showed significant positive physiological changes, particularly related to functional wellbeing. Other research has shown that individuals with access to green natural spaces during recovery from cardiac surgery experienced a range of benefits, including improved physical health and elevated feelings of wellness. They were also more likely to choose regular exercise once rehabilitation was completed.

Children's and young people's health

Children with access to natural green spaces receive greater physiological benefits than those that play indoors. Children with access to parks are less likely to be overweight or obese, and other reported benefits include better eyesight.

Health promotion advocates who investigate the time children spend in public green spaces are particularly interested in variables such as:

- being able to walk to parks
- the relationship to levels of neighbourhood
- perceptions of safety in a park
- cultural norms, and
- attitudes towards outdoor physical activity and park use.

Implicit in the notion of accessibility 'on foot' is the understanding that children who live closer to parks are likely to access them more frequently than children that live further away. In addition to the obvious potential for accessible parks to foster outdoor play, access to safe public parks that results in frequent use is also likely to result in less stress for children in culturally and linguistically diverse (CALD)/low socioeconomic areas, and to increase the likelihood of selecting active transport (walking and cycling) as a method of accessing local green spaces.

In a study by Cheng and Monroe (Cheng & Monroe, 2012), children's connection to nature, their previous experience in nature, their family's perceived value of nature, and their perceived sense of control of nature was found to positively influence their interest in performing environmentally friendly behaviours.

Access to safe and appealing parks, particularly with facilities seen by adolescents as desirable (e.g. basketball courts, skate ramps), has provided a physical outlet for young adults from CALD communities. Park use by CALD communities can reverse perceptions of vulnerability and social exclusion.

Stress relief

The quality, quantity, and accessibility of green spaces has been shown to have a significant inverse relationship to stress among populations, especially in urban areas. Accordingly, there is increasing interest in the stress reduction potential of nature exposure in various forms, especially for individuals requiring physical recovery (hospital/rehabilitation), those in high-risk categories for compromised health, and for disadvantaged communities. Given the considerable contribution of prolonged feelings of stress to the onset of chronic disease (particularly stresses associated with urbanisation), the stress reduction capacity of accessible green spaces should not be underestimated.

1.6.2 Mental/cognitive health benefits

Natural outdoor spaces are a valued, multidimensional resource for promoting positive mental health and associated wellbeing. Aside from psychological wellbeing, the effects of nature on cognitive function in adults are among the most researched psychological outcomes related to passive or active recreation outdoors. Although the psychological effects of exercise in green spaces are less clearly understood than the physical benefits, evidence is accumulating progressively, and numerous synergies exist between the two areas. Louv (Louv, (2008)) recognises that the negative consequences of nature deficit exist for children and adults alike.

Mental health rehabilitation

Urban living has been identified as a key factor that contributes to stress and mental ill health. The impact of chronic stress associated with urban living is well recognised – chronic stress leads to a number of conditions associated with poor mental and physical health and contributes to a reduced quality of life. In this context, the contribution that being in nature makes to promoting healing and restoration is well documented. The restorative effects of exposure to parks and green open spaces give rise to countless personal benefits, such as recovery among individuals experiencing clinical conditions associated with anxiety and depression, chronic stress such as post traumatic stress disorder (PTSD), reduced attentional fatigue in employees, and attenuation of hyperactivity in younger populations. Additional benefits include the evocation of positive emotions, reduction of sub-clinical depressive/anxious states, and an increased feeling of individual resilience. In recent years, there has also been a growing awareness that people with dementia should have the necessary environmental support and freedom to access the outdoors (Cook, 2015).

Alterations to mood

Connection to nature is vital not only to disease prevention, but also for positive psychological states. Stress attenuation via feelings of connection to nature is closely linked with favourable mental and emotional health outcomes. This is particularly true for populations with sub-clinical depression, who report increased recovery after time spent outdoors.

Research investigating the connection between mental health and green spaces recognises that living in close proximity to useable parks and green spaces significantly mediates individual resilience and life coping skills. Stigsdotter and colleagues (Stigsdotter, (2011)) reported that "*respondents living more than 1 kilometer away from a green space have 1.42 times higher odds of experiencing stress than do respondents living less than 300 metres from a green space."* Additionally, Stigsdotter et al. note that people may visit parks for different reasons. For instance, participants who were stressed were more likely to visit local parks with the aim of restoring their mental state.

Exposure to the natural sounds experienced in parks also enhances mood recovery. Although some measurement limitations are acknowledged within the empirical literature, decision-makers should not ignore the importance of these restorative factors.

In urban environments, access to parks or green spaces has the potential to promote wellbeing through attention restoration and stress reduction. Astell-Burt (Astell Burt, et al., 2013) report that undertaking passive activities in parks can reduce psychological arousal by reducing blood pressure. Attention restoration increases achieved after sitting in a park for 15 minutes may contribute to the prevention of stress-related disease. Adults who exercise in local parks often report mental health benefits such as improved relaxation and stress management, which improve their capacity to disconnect from work/family/daily life.

Cognitive development in children

Blanchet-Cohen and Elliot (Blanchet-Cohen & Elliot, 2011) identified that affording children opportunities to visit parks provides engagement, fun, and education. The authors also noted that children can also 'discover nature' in the form of trees, plants, animals, insects and terrain. Additionally, it is well established that opportunities to play in parks allow children to explore the diversity of protective factors offered by experiencing nature, capitalising on the chance to practise reasoning, reaction, observation, logic, attentiveness, responding to the environment and people, way-finding, spacio-temporal relation, and task accomplishment.

Children with behavioural or learning disabilities report being able to focus better after spending time in natural outdoor settings. Parks and local green spaces are therefore considered to be valuable resources for primary education. As Olsen (Olsen, 2013) states: "*Outdoor settings, not limited to school grounds or gardens, should be considered as an extension of the classroom in terms of enriched learning and development opportunities.*"

1.6.3 Social and spiritual health benefits

Some authors have suggested that "social health in city neighbourhoods may be deteriorating because modern urban planning and design has in many cases failed to adequately provide for attractive public spaces for residents to gather, interact, and develop relationships" (Baur, et al., 2013). Therefore, parks and other green spaces are vital for promoting social cohesion and social capital in urban communities.

Social cohesion

Interpersonal trust, social cohesion and reciprocity are key features of social capital that are facilitated by the availability of parks and quality open spaces. Park specific social interactions (i.e. informal communication with others) are recognised not only as key mediators of social health perceptions among urban residents, but also moderate stress by fostering social support.

Other forms of natural environments have also been found to foster social health. Community gardening, for instance, is considered a trending topic within the nature and human health domain. Particularly within Australia, this topic has received in-depth examination, and as such community gardens are now recognised as "pillars of social justice and environmental equity; they are places where people can literally seek community." (Porter & McIlvaine-Newsad, 2013)

In the USA, Baur, Gomez and Tynon (Baur, et al., 2013) conducted a study of 1,000 adults from the Portland metropolitan are to test whether urban nature parks, within walking and within driving distance of peoples' homes, had a positive relationship to these adults perceptions of the self-reported social health of their neighbourhood. The findings were that there was a significant and positive relationship, for both walkng and driving distances, to neighbourhood social health. These findings were not influenced by socio-demographic variables and were regardless of whether participants were park users or not.

Sense of place

'Sense of place' is another relevant, place-based theory that recognises the spiritual connection that indigenous (and non-indigenous) people have with their country or 'place'. It is defined as a long-lasting emotional attachment or positive connection between a person and a location. Spirituality could be an important aspect of people's sense of place with nature and may have flow-on benefits for their spiritual health and wellbeing (Kamitsis, 2013).

The notion of place connection is particularly important to those who are vulnerable to social exclusion or marginalisation. The literature places particular attention on the potential for place attachment to accessible green spaces (e.g. gardens) among people experiencing physical displacement, such as refugees or those undergoing in-patient treatment.

In older adults, proximity to natural outdoor spaces is correlated with greater life satisfaction. Despite the frequent reporting of spirituality within the context of the human health/nature connection, empirical exploration of the spiritual dimension is generally absent or vague. (de Witt, 2013) Existing gaps in the empirical literature may be attributed to difficulty in measurement, or to cross-over with other psychological/emotional concepts, such as the wellbeing, restorative and therapeutic benefits derived from nature.

3.7 Are there other benefits of an urban forest?

3.7.1 Property values

Street trees and open space have been shown to affect property prices both in Australia and overseas. A literature review by the Victoria Institute of Strategic Studies (Symons, et al., 2015) noted that the presence of trees increased the selling price of residential units between 1.9% and 9%. The review noted that the proximity of open green space also correlated with an increase in property sales prices. The size of the increase was dependent on several factors, such as the area of open space, its proximity to housing, the type of open space, and the method of analysis. Large natural forest areas have a greater effect on nearby property values than smaller urban parks, playgrounds, and golf courses.

Research into property values dates back to the 1850s, when landscape architect Frederick Law Olmsted conducted a study of how parks influence property values. From 1856 to 1873, Olmsted documented the value of property immediately adjacent to New York's Central Park in order to justify the $13 million spent on its creation. He found that, over the 17-year period, there had been a $209 million increase in the value of the property covered by the park. Another component of Olmstead's study was increased tax revenue as a result of the park. The annual excess of tax increase from the property value was $4 million more than the increase in annual debt payments for the land and its improvement. It was concluded that New York City actually made a profit from building Central Park (Symons, et al., 2015).

Engineering firm AECOM's Brilliant Cities Report (AECOM, 2017) on green infrastructure estimated that an increase of 10% in the leaf canopy of street trees alone could increase the value of Sydney properties by an average of $50,000 per unit (based on three suburbs).

3.8 What other factors influence urban forest design?

Many different parameters play into the final form and extent of an urban forest, and they include:

- Ecosystem Disservices (Escobedo, et al., 2011) – urban vegetation can have negative impacts, such as the cost of maintenance, social nuisances such as allergens, and environmental impacts such as the displacement of native species. Disservices can be attributed to green spaces or specific plants. Care needs to be taken that the negative consequences do not outweigh the benefits.
- Thresholds and correlations of the benefits from green space – the size of parks, the distance to parks, and green streetscapes correlate to human health and wellbeing. There are relationships between tree canopy cover and the removal of particulate matter, shade and tree canopy cover, and carbon sequestration and tree biomass. In addition, a variety of green spaces and green space characteristics have been identified as supporting biodiversity.
- Green space targets – these are typically related to the goals of a greening program such as human health (increasing physical activity) or ecosystem services (e.g. cooling). The amount of park space or canopy cover is a common target, and taxonomic diversity also widely used.
- The physical environment shaping the benefits provided by the urban forest – climate is a significant driver for the distribution of plants and a predictor of tree species and diversity. Highly urban areas tend to be warmer, the soils drier, and there are variable pollution and

nutrients inputs. These factors affect the species configureuration and structure of green spaces.

- The social context shaping the benefits provided by the urban forest – social factors that influence the way people think about and use the urban forest include population density, socioeconomic inequality, gender, social values, culture and age.
- Governance and policy shaping the urban forest - a range of policy mechanisms, including information and engagement, incentives and encouragement, government provision, and regulation and legislation are required to support the inclusion, retention and maximisation of green space in cities, as well as addressing both public and private land tenure (Kendal, et al., 2016).

4 Key influences of metropolitan Melbourne's urban forest

This chapter discusses some of the risks to Melbourne's urban forest. It also considers the importance of Water Sensitive Urban Design and how urban development has shaped our urban forest. Further, it discusses what ongoing effect urban development is having on the urban forest. Additionally, it summarises some of the current actions that local government and others are taking to manage our urban forest, including international examples.

4.1 What are the risks to Australia's urban forest from climate change and urban heat?

In 2016, research undertaken for the City of Melbourne and published by the Clean Air and Urban Landscapes Hub identified tree species' vulnerability to future temperatures. It found that, out of the approximately 375 species and 63,000 trees currently planted in the City of Melbourne, up to 55% of trees were vulnerable to climate change in an extreme furture climate scenario (Kendal & Baumann, 2016).

The research identified that two groups of species were particularly vulnerable: those from colder climates (e.g. Europe and North America), and species with narrow climate envelopes, which include many locally indigenous and other native trees such as *Eucalyptus* spp. and *Acacia* spp.

Following this study, in November 2017 the Clean Air and Urban Landscapes Hub released a national analysis of the 'Risks to Australia's urban forest from climate change and urban heat' (Kendal, et al., 2017). The study analysed the risk of temperature increases to 1.9 million trees in 29 LGAs across Australia, including 10 from metropolitan Melbourne (over 817,000 trees assessed). Every tree was analysed to see how close its known temperature tolerance limits were in: (a) current climates, (b) to an emissions-limited climate change scenario by 2040 assuming emissions stabilisation, and (c) a business as usual emissions scenario by 2070. Whilst noting that there was a high level of variation in the risk both from city to city and across areas within each city, it found that by 2070:

- 15% of all public trees (23% of species) in Australia's cities are at high risk (red flagged) from increased temperatures in the emissions-limited climate change scenario (Figure 8)
- 25 of all public trees (37 % of species) are at risk in the business-as-usual emissions scenario by 2070, and
- a further 34 % of trees are at some risk (yellow or orange flagged) in the emissions limited scenario and 29 % in the business as usual scenario.

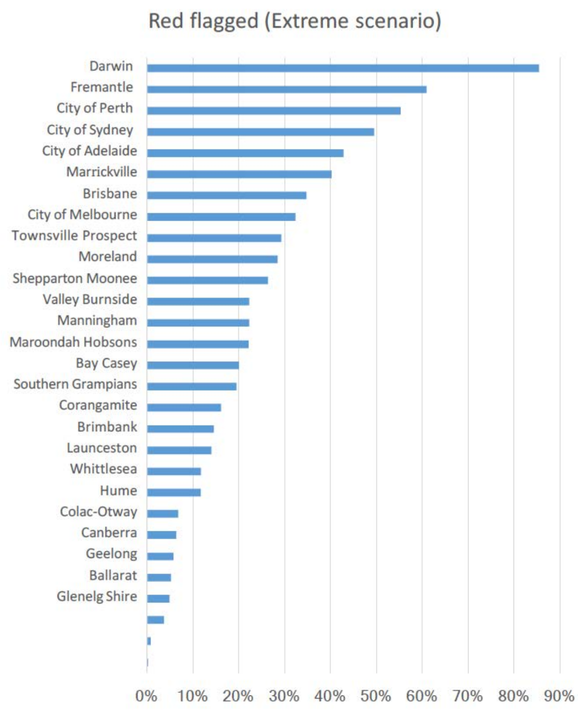


Figure 8 The proportion of trees red flagged in each LGA under the business-as-usual climate change scenario (Kendal, et al., 2017)

4.2 What is the role of water sensitive urban design in Melbourne?

Water Sensitive Urban Design is an aspect of Integrated Water Management (Furlong, et al., 2015), (Kuller, et al., 2017) and the outcome of combining historically separate objectives: flood protection, waterway health, urban liveability and climate change adaptation (Kuller, et al., 2017). Water Sensitive Urban Design aims to keep water that was traditionally disposed of via the stormwater system to surrounding waterways and bays within the urban landscape. It is implemented through a combination of policy (e.g. stormwater quality and reuse targets) and green infrastructure developments to help achieve policy targets. Water Sensitive Urban Design is focussed on “incorporating sustainable urban drainage systems, also known as green infrastructure, and reuse schemes into urban planning. This is done to improve liveability outcomes, through providing plants and trees in streetscapes, and environmental outcomes through protecting waterways from the damaging effects of urban stormwater runoff” (Furlong, et al., 2016). Examples of Water Sensitive Urban Design include rain gardens, man-made wetlands, grassed or landscaped swales, porous pavements, street tree pits, and open space irrigation using treated stormwater.

The benefits of stormwater retention within the urban environment include:

- Protection of creeks, rivers, wetlands and harbours from polluted stormwater runoff
- Reduced flooding
- Reduced use of potable water for non-potable needs (e.g. irrigation)
- Improved soil moisture and health
- Decreased urban heat island effects and
- Increased healthy green infrastructure with associated amenity value

Water Sensitive Urban Design can mitigate the urban heat island effect (Coutts, et al., 2012). It can ensure that green plant infrastructure is well irrigated (through redirected stormwater), and that new plantings can be established and maintained. Green infrastructure (trees, wetlands, water infiltration systems, stormwater harvesting and reuse schemes etc.) established to manage stormwater flows can support large trees and increase available shade, while the general greenery and open water components impact the evapotranspiration cycle (the movement of water from the land and vegetation into the atmosphere). Water evaporates from wet/moist surfaces such as lakes, wetlands, and soil, and plants transpire as part of the photosynthesis and plant temperature control processes. The evapotranspiration process extracts heat from the atmosphere (via latent heat of water vaporisation) and leads to cooling. A literature review by Qui (2013) noted that "vegetation in urban areas can reduce the surrounding temperature by 0.5°C to 4°C" (p. 1309), while "the presence of water bodies can reduce the air temperature by several degrees, depending on the size of the water body and distance from the water's edge" (Qui, et al., 2013).

4.3 What is the status of Melbourne's metropolitan councils' urban forest initiatives?

A review of the plans and strategies of all 32 Melbourne metropolitan councils (also termed local government areas) found that the urban forest is acknowledged as a valuable and vital asset and that it makes a significant contribution to the liveability of the city. Some councils use the i-Tree Eco (iTree, n.d.) software to assess the forest benefits and determine an associated dollar value. Across the plans, the threats identified are similar. The main threats facing the urban forests included climate change and associated temperature and rain variability, urban heat island effect and heat retention, infrastructure infringement, urban densification and associated habitat loss. Solutions to these and other challenges included increasing tree diversity to accommodate greater climatic variability and resistance to potential pests, increasing the canopy cover to manage the urban heat island effect, using green space to better manage stormwater, and creating corridors to reduce forest fragmentation.

Many local government authorities address these threats with a range of discrete medium-term (5-10 years) strategies that address a specific issue (e.g. climate change) or a specific component of the urban forest (e.g. open spaces, street trees, parks), and the various councils are at slightly different stages regarding the evolution of their urban forest-related plans. Some councils are focussed primarily on the public domain of street trees and open spaces; others have expanded their focus to include biodiversity and connectivity, and yet others include green infrastructure, water management, and the private realm. There is generally a strong focus on street tree planting and management, and most strategies or plans focuss on public vegetation. Councils acknowledged that private trees and greenery had an equally important role as public vegetation, but access to and control of this sector were challenging.

Thirteen councils have some form of urban forest strategy and the primary focus is on trees and canopy cover. The existing strategies tend to be long-term (>10 years), use a broad definition of an urban forest, have performance measures (typically canopy cover, tree diversity), and address to some degree vegetation on private land (primarily via community engagement programs or a significant tree register). For many, though, there is still a heavy focus on street trees and the public realm. For some councils, the urban forest strategies are structured so that it is possible to see how the goals and targets feed into the greater network of strategies i.e the overall council strategy, urban design, water management and climate change.

A key measure of an urban forest is canopy cover, which is an indication of its current state and a useful measure of progress. All thirteen councils have established an urban forest canopy cover target. For example, the City of Melbourne aims to increase the public realm canopy cover from its current 22% to

40% by 2040. Port Phillip identified streets with low canopy cover (0 to 10%) and will prioritise these neighbourhoods for further tree plantings. It also has set a target percentage increase in canopy cover for each neighbourhood. The Yarra intends to increase its total canopy cover from 17% (2014) to 21.25% by 2040 – an increase of 25% – while the Moreland intends to double its total canopy cover (from 14% to 29%) by 2050. Whittlesea and Knox specifically state their goal increases in terms of streetscape canopy cover, while Brimbank and Wyndham have total canopy cover targets, and separate, open space and private canopy targets. Setting goals for private canopy cover are particularly challenging, as these directly impacts land development. However, several councils have done so. For example, Banyule's goal is to increase canopy cover on non-council managed land by 20% within 15 years, while Moreland's goal plans to ensure that its current private realm canopy remains at 9%. Wyndham acknowledges the differences between established private realm and new developments and has set two targets: a 15% canopy cover for established areas, and 10% canopy cover for new areas by 2040.

While increasing natural infrastructure is one avenue for expanding the urban forest, protecting the existing natural infrastructure is another. There are several ways to achieve this, and a key building block is establishing a detailed and current database. Knowing the composition and state of the urban forest provides the foundation for planning and moving forward. At least 25 councils have a comprehensive street tree and/or park database, although formats and depth of data vary. For the private realm, detailed databases do not exist. At least nine councils have a significant, exceptional, or heritage tree register, and another six are in the process of developing one. These registers primarily capture private trees but may included notable public trees. Trees are typically nominated by the community for their local significance. The registers, however, contain only a handful of all private trees (e.g. the City of Melbourne's Significant Tree register lists about 200 trees, Casey's approximately 1000, and Moonee Valley's approximately 100 trees). Banyule also includes significant areas of vegetation in its register.

Tree protection includes protecting trees and vegetation in construction zones, establishing clear guidelines for removal, ensuring removal is a last resort, and establishing a penalty system that will deter damage and unpermitted removal. The City of Melbourne has established a compensatory valuation equation for its street and park trees that incorporates an amenity, basic, and species value along with a removal cost. For large trees, the total value could easily reach six figures, which may encourage developers to consider alternative solutions to removal. The valuation also provides a foundation for determining penalty costs for damage or unpermitted removal. Examples of other councils that have established public tree valuation methods include Wyndham (which had established a method based on the cost of removal and replacement along with an economic benefit factor incorporating the tree height), Brimbank (which used the Modified Burnley valuation method) (Moore, 1991), and Knox (which used the City of Melbourne's method) (City of Melbourne, n.d.).

The purpose of requiring a local law permit to remove trees is to both regulate (deter) tree removal so that only those trees that should be removed (causing property damage, poor health, structural faults resulting in the risk posed by the tree outweighing the benefits provided, etc.) are given a permit to be removed; and to ensure a continuation of canopy cover by requiring a replacement tree be planted as a condition of the permit.

The three main planning overlays used to protect vegetation under the Victoria Planning Provisions are the:

- Vegetation Protection Overlay
- Environmental Significance Overlay
- Significant Landscape Overlay

Each of these overlays have, in addition to their other objectives, the objective of deterring unnecessary tree removal. There are often also references to the retention of trees throughout planning schemes in residential development policies, Green Wedge policies, structure plans, etc.

The maximum fine for a tree protected by a local law is $2,000; for a tree protected by a planning scheme the amount is substantially higher. The legislation under which the tree is protected includes sections outlining penalties for breaching that legislation.

Brimbank's Urban Forest Strategy action list includes investigating options to record all trees on private land, while Wyndham's City Forest and Habitat Strategy aims to ensure all significant trees on private land are nominated and protected by 2040. Under council law, a significant tree is usually defined by its size and its circumference at a certain height above the ground. Pruning or removal of such trees requires a permit. However, as there is no comprehensive database of private trees, pruning and removal can occur without council's knowledge. There are penalties for non-permitted activities, such as for Port Phillip, where the penalty is twenty penalty point (currently equivalent to $2,000). If a council maintains a 'significant', 'exceptional' or 'heritage' tree register there is less chance that a non-permitted activity will occur. The penalty for such a planning infringement can be several penalty points (e.g. for Banyule and Moonee Valley it is five penalty points for an individual), and in some situations, tree reinstatement or remediation may also be required.

Urban forests face a variety of threats, and providing for a diversity of plant species, genera and families is one means of improving their resilience. The greater the diversity, the lower the risk of a single event – such as a pest or extreme heat event – destroying large sways of vegetation. Diversity includes different tree ages, species, growth rates, and degrees of health. At least five of the Melbourne metropolitan councils have included diversity targets for the street and park trees in their urban forest strategy, and several others have indicated that the diversity needs to improve. As little is known about private trees, diversity targets for this sector have not been set.

The primary focus of the diversity targets are species. At the time of this review, the City of Melbourne had set a goal of no more than 5% of any one species, 10% of anyone genus, and 20% of any one family. The council also set as a target that no more than 10% of the tree population will be in poor health by 2040. In contrast, Wyndham had set a target of no more than 10% of a species, 20% of a genus, and 30% of a family by 2040, while Brimbank had set a limit of a maximum of 50% of one family and intended to introduce additional families.

A healthy urban forest requires water, particularly during the plant establishment phase. Increased variability and unpredictability in weather patterns due to climate change is likely to make consistent and economical irrigation difficult. Banyule and Brimbank highlight the need to further embed Water Sensitive Urban Design in all of their development for the benefit of the total urban forest.

The councils recognised that, to achieve a healthy, connected fabric of urban forests, a collective effort was needed. Port Phillip, in its latest long-term strategy (2017–2027) (City of Port Phillip, 2017), identified the need to work with inner-city councils on an urban forest and biodiversity strategy. Four Local Government Authorities with urban forest strategies were members of Greening the West, and six were members of the National Urban Forest Alliance. Greening the West program was developed through a collaboration of nine western Melbourne metropolitan councils whose goal was to maximise urban greening by doubling the canopy cover and increasing green space. The National Urban Forest Alliance aims to promote and grow healthy, resilient urban forests across the nation through partnerships, research, information sharing, and guidelines. All ten councils, along with several other bodies and community groups, are working together to link up green spaces across their councils to protect natural areas and create a world-class urban ecosystem.

4.4 What have been the impacts of urban growth and densification on the urban forest?

The history of Melbourne's development and growth has had an important effect on the shape and form of the urban forest. This section briefly describes what this effect has been in relation to residential urban form.

4.4.1 Early development patterns

Preferences for elevation, views, water, and mature trees meant that Melbourne's early development was outwards, from the original settlement on the banks of the Yarra to the north-east, east, and south-east, and tended to be on the hillier treed terrain (Presland, 2008). The flatter northern and western (largely grassland) plains were considered less hospitable and desirable. This pattern of development along ridgelines is still revealed to some extent in the current location of open space along waterway corridors and of green wedges that separate development areas (Bush, 2017).

4.4.2 Residential subdivision

Much of Melbourne's residential development up until about 1990 consisted of detached houses that took up about a third of the lot, and a large backyard (Hall, 2010). This facilitated a backyard of 150 to 400 square metres. The common, back-to-back backyard pattern (Figure 9) created large, contiguous areas of private open space that had ecological, cooling, aesthetic, stormwater runoff, family security and recreational benefits.

Figure 9 Contiguous back-to-back backyard vegetation, Eastern metropolitan region, Victoria 2010.

However, since then, the trend has been towards larger houses on smaller greenfield plots and urban infill in established urban areas, which includes medium to high density development of townhouses and apartments. This has reduced lawn and garden sizes and increased impervious surfaces (Figure 10). At the same time, the plot coverage of dwellings has increased. A comparative study contrasted the plot ratio of older established suburbs to newer suburbs (Hall, 2007) and showed a difference in the range of 30% plot coverage in the older established Melbourne suburbs to 65% in a newer suburb in Melbourne. This pattern was repeated across Australia and accompanied by urban form dominated by narrow lots with deep or square plan houses that resulted in little usable green space.

(a) 1996 (b) 2018

Figure 10 Redevelopment of three lots in the Eastern metropolitan region.

Note the loss of vegetation that is evident between images (a) and (b) before and after redevelopment and the large areas of impervious surfaces in impage (b). (Source: Explore Whitehorse http://maps.whitehorse.vic.gov.au/)

A further study found that almost all new suburban houses have minimal provision of soft-landscaped, private open space (Hall, 2010). It noted that this is happening irrespective of the size of the lot and seems connected with a trend to larger dwellings in relation to the lot area (Figure 11). The result of infill development is illustrated in Figure 14 with (a) before an (b) after infill development being illustrating a loss of private green space in Eastern metropolitan region, Melbourne.

> *"During the 1990s, the physical form of new suburban development in Australia changed dramatically. Houses with large backyards ceased to be built. Suburban form since then has been characterised by dwellings which cover at least 40% of the lot. Such houses have a deep or square plan with minimum wall length, few windows, an integral garage, often single-storey. These trends have resulted in a diminution of the backyard in both shape and total area. This has reduced the amenity of the property in terms of outlook from the dwelling and facilities for outdoor recreation around the home, especially for young children. However, the disadvantages go way beyond the lifestyles of the occupants. There is a loss of biodiversity and an increase in run-off of storm water. The microclimate becomes hotter and this, in turn, requires more air-conditioning and increased energy use. Moreover, it represents a permanent change in building form that cannot be corrected later." (Hall, 2010)*

(a) 2010 *(b) 2018*

Figure 11 Infill development illustrating loss of backyards and vegetation in Eastern metropolitan region, Melbourne

4.4.3 How current urban form affects landscaping

A 2017 study of inner suburban Melbourne found that as the density of a development increased, both the proportion of trees on a lot, and the soft landscaping, decreased (Stanford & Bush, 2017). Interestingly, this study also found a preference for trees over smaller vegetation types when available space is limited. Research in the cities of Boroondara and Yarra noted that, while there were significant losses of trees on private property due to densification, this had been partly offset by an increase in public land planting, mostly in streets and in parks (Moore, 2009). However, the study also noted that, even on public land, spaces for larger trees were limited. As a result, public land plantings were not likely to be able to make up for the loss of canopy trees in private spaces.

4.4.4 The result of greater densification on urban heat

The Western Adelaide Urban Heat Mapping Project Report clearly identified surface temperature differences in low (Fulham), medium (West Croydon), and high (Northgate) density residential zones (Seed Consulting Services: Airbourne Research Australia and EnDev Geographic, 2017). The more compact urban form provided less space for greening to mitigate the warming effect of impervious surfaces such as driveways, roads, and dark roofs. High density areas of Northgate were found to be 2.9°C warmer (and 2.0°C above average) than the low-density areas of Fulham. Figure 12 below shows surface temperatures in low (Fulham), medium (West Croydon) and high (Northgate) density residential zones.

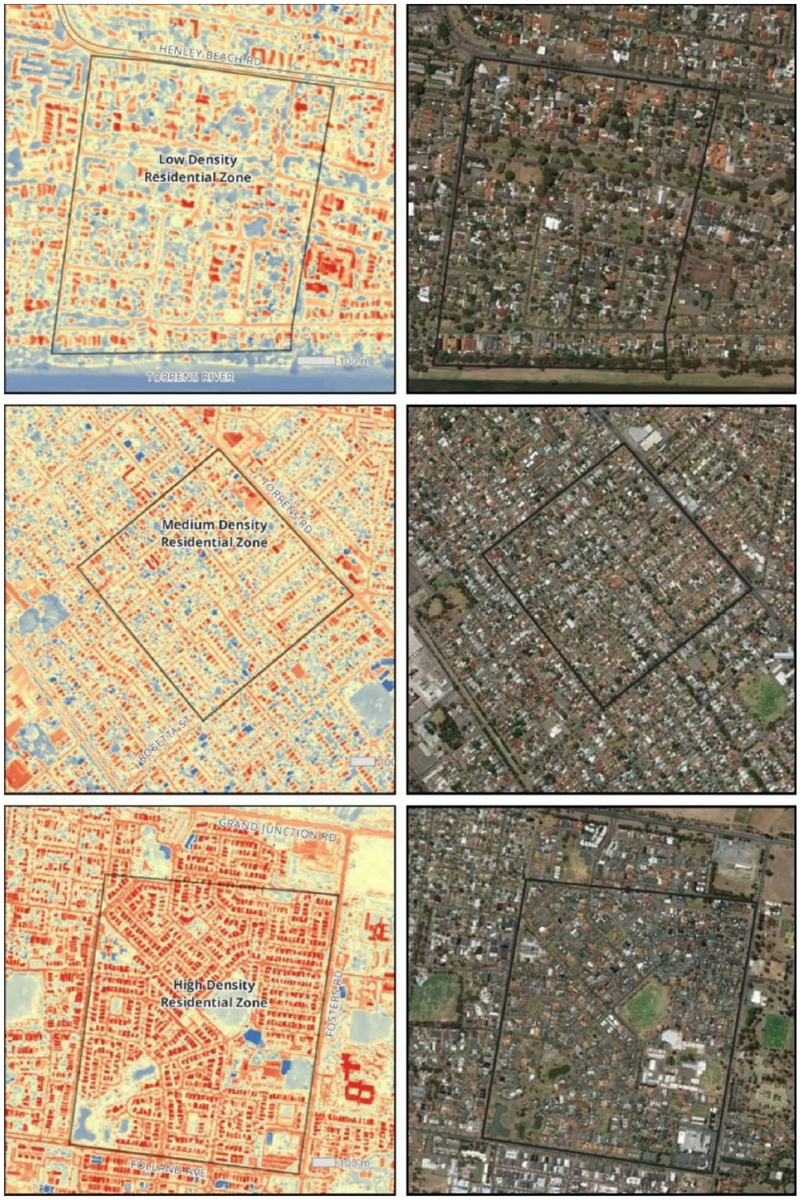


Figure 12 Surface temperature differences in low (Fulham), medium (West Croydon), and high (Northgate) density residential zones (Source: Western Adelaide Urban Heat Mapping Project Report)

A study on the equitable provision of shading through tree canopy in western Melbourne included both online and in-depth interviews with local government officers and Victorian Government staff (Cook, et al., 2015). The interviews focussed on cultural and behavioural change, the potential for regulating in favour of private space trees, and additional roles for local government. The interviewees acknowledged that tree canopy cover in private space faced many challenges, including the reduction of average lot size, larger house sizes, in-fill development, and the move toward ‘zeroscaping’ private gardens (which results in water saving but also less vegetation). The study noted agreement that the governance of the urban canopy was complex and involved many local governments, utilities, developers, Victorian Government and residential stakeholders. Despite the known benefits of trees, most are not protected by planning or environmental controls. Also, as the majority of the urban forest is located on private land, the integrity of urban forest strategies depend on the activities, values and perceptions of private landowners and residents. Survey respondents were of the view that, while about 65% of residents were engaged in urban forest stewardship, this left a sizeable percentage whose attitudes ranged from indifference to hostility towards this task.

Local government's urban forest strategies acknowledge that private land is a vital component of the urban forest and are trying to ensure that, as far as practicable, it is protected and enhanced. As an example, the Brimbank City Council's urban forest strategy states the following:

P23 *Private land accounts for the majority of land ownership in the Brimbank area. Whilst Council develops and improves the Urban Forest on land it manages, it currently has limited control on private land such as residential and industrial areas.*

Private land owners must be engaged in the development of the Urban Forest. Without the Urban Forest on private land, Brimbank will not be able to achieve 30% canopy cover to improve liveability. There will also be the potential for reduced permeability such as paving for driveways, parking and outdoor areas.

P42 *Brimbank has already made progress to create better landscape outcomes, which includes residential developers being required to include tree planting within the development. Two lot subdivisions will be required to plant two medium trees in the front of the property and a small tree to the rear of the property to shade surfaces and reduce heat island impacts. The developer will also be encouraged to provide permeable surfaces such as permeable paving, rain gardens and grassed areas to minimise water entering into the Brimbank drainage system. This amendment to the Planning scheme will ensure strong Urban Forest outcomes for new development.*

Brimbank will also encourage further environmental design principles such as Green Roofs, Green Walls and other vegetative features that help to mitigate the impacts of heat in residential areas (Brimbank City Council , 2016).

The above discussion illustrates the impact of urban densification on the urban forest. Examples of the impact of infill development in established suburbs on urban vegetation are common; three are provided below.

Figure 13 illustrates where three allotments with three detached dwellings (on the left) have been re-developed to yield eight dwellings. This resulted in a gain of five dwellings, but with a significant loss of on-site vegetation and a gain in impervious surfaces.

(a) 2010 *(b) 2018*

Figure 13 Redevelopment of (a) three allotments with three detached dwellings, to yield (b) eight dwellings (Source: Nearmap)

Figure 14 illustrates a similar re-development of four allotments with four detached dwellings (on the left) to yield twelve dwellings. This led to a gain of eight dwellings but also a significant loss of vegetation and a gain in impervious surfaces

(a) 2010 *(b) 2018*

Figure 14 Redevelopment of (a) four allotments with four detached dwellings, to yield (b) twelve dwellings (Source: Nearmap)

In contrast, Figure 15 illustrates a higher-density development that provides for significant private green space with 18 households on approximately 3000 m^2 (Community, n.d.).

Figure 15 Northern metropolitan region, Melbourne (Source: Nearmap)

4.5 What domestic case studies are there of actions to protect the urban forest?

4.5.1 City of Melbourne Urban Forest Strategy

The City of Melbourne's Urban Forest Strategy 2012–2032 (City of Melbourne, n.d.) was an outcome of the city's overall plan and vision to be "one of the top ten most liveable and sustainable cities in the world" (Victoria State Government. Department of Environment, Land, Water and Planning, 2013), and it is a key component of the refreshed strategy (Future Melbourne 2026) (City of Melbourne, 2016). A healthy urban forest helps address the original community vision for Melbourne as outlined in the Future Melbourne plan that is a city that works within its environmental means, and the revised 2026 goal of a city that cares for its environment. In addition to the Urban Forest Strategy, the 2012 Open Space Strategy (City of Melbourne, 2012) and the 2017 Nature in the City Strategy (City of Melbourne, 2017) outline three strategies to achieve these goals. These strategies fit within the broader 2017 Climate Change and Adaptation Refresh (City of Melbourne, 2017), 2014 Zero Net Emissions (City of Melbourne, 2014), and 2014 Total Watermark Strategies (City of Melbourne, 2014).

The City of Melbourne's urban forest definition is broad and encompasses trees and vegetation, soil and water, private and public realms, and an array of different green spaces. In 2012, the Urban Forest Strategy outlined Melbourne's urban forest benefits and assigned them an estimated amenity value of

A$700 million. Climate change, population growth, and urban heating were identified as the primary threats to maintaining an urban forest that was resilient, added to the liveability and sustainability of the city, and created community health and wellbeing.

The Urban Forest Strategy identified six strategies and six associated targets, which were implemented via specific and broader actions. The first level action was the application of an overarching 'Green Governance Philosophy'. This philosophy accepts the need to work across administrative, discipline and regional boundaries to share knowledge, communicate, and create integrated action. The process included local community and business entities, national bodies, and global expertise to ensure creative and effective solutions to a healthy urban forest could be implemented. The Green Governance concept is reiterated in the 2017 Nature in the City Strategy.

Strategy 1 in the Urban Forest Strategy is to increase the public realm canopy cover from 22% to 40% by 2040. The key mechanisms to achieve this were the ten Urban Forest Precinct Plans (City of Melbourne, 2015), which provide specific details about where, when and what will be planted in each street across the municipality. The rationale for ten smaller rather than one overarching plan was to reduce the complexity and workload into manageable subsets, capture unique local features, and draw in local community values and vision. The Urban Forest Precinct Plans determine key planting constraints, opportunities for major redesign, and street planting prioritisation for 2013–2023. They also highlight biodiversity corridors and connectors between open spaces. The 2012 Open Space Strategy covers public parks and gardens within the various precincts and emphasises the greater use of large canopy trees to assist with urban heat reduction, improved biodiversity, and managed water runoff. Specific precinct principles and the 2011 Urban Forest Diversity (City of Melbourne, 2011) guidelines define the choice of tree species. In addition to the Urban Forest Precinct Plans, there are planting plans for several major boulevards.

The Urban Forest Precinct Plans are living documents that are evolving over time. While the primary focus for the first period was on street trees, the second 10-year planning period aims to expand on the initial biodiversity, corridor, connectivity and understorey plantings to incorporate the results of the 2017 Nature in the City Strategy outcomes. The Nature in the City Strategy aimed to address ecosystem health and biology, urban landscape connections, private realm participation, and continued excellence in urban ecology innovation. As urban ecology is a relatively new field, many of the actions in the Nature in City Strategy focused on research, data collection, and learning.

While the expansion of the public realm canopy is one element of the Urban Forest Strategy, the other is the protection of the existing canopy. The City of Melbourne has an efficient Tree Removal and Retention Policy which enables pre-emptive protection when construction work takes place near trees. It also manages pruning and maintenance, and oversees permitted tree removal. An Exceptional Tree Register was established for the protection of trees on private property.

Strategy 2 in the Urban Forest Strategy is to increase urban forest diversity. The target is to have no more than 5% of any one tree species, 10% of any one genus, and 20% of any one family. In addition to species, diversity must include other factors such as age and growth rate. The 2011 Urban Forest Diversity Guidelines is the primary tool for achieving this. A selection process and subsequent array of street and park location types have been identified. For each location, the minimum conditions for successful planting have been identified, along with a list of suitable trees. The selection process has taken into consideration a wide range of factors (e.g. vulnerability to pests and pathogens, drought tolerance, heat tolerance, street arrangement, maintenance, attractiveness). In addition to street and park trees, the Urban Forest Strategy aims to improve structural diversity by encouraging green walls, green roofs, and green laneways via four major projects – the Urban Forest Fund, 2014 Growing

Greening Guide, Green Roof Project Map, and the Greening Laneway. These projects also aim to engage the private sector in the process.

Strategy 3 aims to improve vegetation health so that 90% of the tree population is healthy by 2040. There are three ways to achieve this. Primarily, urban forest health is delivered through a careful maintenance program that consists of on-ground care and proactive research and innovation. The second way is via the 2014 Total Watermark Strategy, a component of which addresses soil moisture to support a healthy urban forest, particularly in the open spaces, parks and gardens. The Urban Forest Precinct Plans comprise the third way towards tree health by addressing local soil and moisture concerns through water sensitive urban design.

Strategy 4 seeks to improve soil moisture and water quality. The target is for sufficient moisture to be maintained to support healthy vegetation growth. The primary vehicles for addressing this are the 2014 Total Watermark Strategy and the 10 Urban Forest Precinct Plans.

Strategy 5 is to improve urban ecology, with the target to protect and enhance urban ecology and biodiversity. The key deliverable is the recent 2017 Nature in the City Strategy, which has as its goals to create a more diverse, connected and resilient natural environment, connect people to nature, and demonstrate leadership in the urban ecology arena. The targets include increasing biodiversity, habitats and ecosystem health, improving corridor connectivity, and engaging the private realm. The strategy requires an extensive list of actions, from mapping, establishing baselines, research and monitoring, through to management, planning, and guidance. Timeframes range from one to ten years.

Strategy 6 is to engage with the community, aiming to improve the appreciation of, and participation in, the urban forest development in both the public and private realms. In the early years of the Strategy, the Urban Forest Precinct plans fulfilled this commitment through an ongoing program of community engagement to co-design the planting plans for each precinct. Since the completion of the Urban Forest Precinct, documents and engagement programs include:

Citizen Forester Program: volunteers are trained to carry out urban forest advocacy, monitoring, and research tasks. The program caters to a range of interests and abilities, and provides a variety of activities that are fun and meaningful.

BioBlitz Programs: BioBlitz programs are events that engage both experts and community members in the identification and collection of data on a range of plant and animal life. The events are diverse and engaging, and have included spotlighting nocturnal animals and insects, recording animal calls, sampling various insect and sea creatures, and photographing animals in their local surrounds.

Urban Forest Visual (UFV): the UFV is an interactive data visualisation that displays a map of tree locations, species, ages, and health. An email address is provided for each tree so that the public can send in information about a specific tree, its health, need for maintenance, or a note of appreciation.

Biodiversity Visual: this is an interactive visual map of the insect biodiversity found in the City of Melbourne. Over 560 insect species at 15 sites (primarily public parks and gardens) were identified and recorded, and the data may be interrogated in a variety of ways to aid understanding of the insect life and presence.

Urban Forest Fund: the City of Melbourne launched the Urban Forest Fund to support alternative greening projects within the council district. The fund provides financial support for green spaces, tree planting, vertical greening or green roofs.

2014 Growing Green Guide: this guide (created jointly with the Inner Melbouree Action Plan group of local governments) is targeted towards projects based in Melbourne and Victoria and aims to assist and encourage those who may be involved in the design, construction and maintenance of green roofs and facades.

Green Roof Project Map: this project involved the mapping of rooftops in the City of Melbourne to determine whether they had the potential to be used for solar, cool or green roofs. The information is available online to assist those interested in adapting their roofs.

Greening the Laneways: this is a world-first interactive map developed to show which laneways in the City of Melbourne are suitable for greening. The possible greening options are based on the available sunlight, exposure to wind, and other physical characteristics. Four green laneways were piloted (Katherine Place, Meyers Place, Guildford Lane, and Coromandel Place) and in 2017 received trees, planter boxes, vertical greening, pot plants, murals and new pedestrian spaces.

4.5.2 Greening the West

Greening the West is a regional initiative that aims to assist communities in Melbourne's west through the expansion of green spaces in all forms, such as parks, reserves, streetscapes, green roofs and walls, private backyards, car parks, sporting fields, and waterways. Key goals include increasing green space by 25% by 2030, increasing the supply of alternative water for green space by 25% by 2030, and doubling tree canopy cover by 2050 (Greening the West, n.d.).

An alliance of advocates from the western municipalities of Brimbank, Hobsons Bay, Maribyrnong, Melton, Moonee Valley and Wyndham developed the Greening the West Strategic Plan. The plan identifies eight key goals and targets that the alliance has committed to working towards to contribute to a green and healthy west. Examples of the initiatives implemented to date include:

One million trees

This project planted one million trees across several major nature links in western Melbourne. In 2018, Victoria's Community Correctional Services commenced an ongoing project to provide gardening services to the 1 Million Trees Project. Services include site maintenance, weeding and watering.

Greening the pipeline

Greening the Pipeline aims to convert 27 kilometres of the heritage listed Main Outfall Sewer between Brooklyn and Werribee into a linear park. The first section at Williams Landing that showcases the concept was completed in 2017. The vision is to create a vibrant space that will connect communities and provide a unique space to meet, play, and relax.

Afton Street Conservation Park Wetlands

The wetland restoration, created in 2010, provides a new open space for visitors to enjoy native plants and wildlife. It also showcases a new and sustainable way of watering green infrastructure. The wetlands capture and recycle urban runoff via five linked ponds in a naturally occurring process. The initial larger pond filters dirt and rubbish from residential stormwater, while the smaller ponds filter out various pollutants and bacteria. The clean water is stored in an irrigation pond and used to water the local sports field.

Exford Primary School

Exford Primary School is an example of how a small targeted greening project can achieve multiple goals: improve aesthetics, create additional habitat, and provide an interactive opportunity for engaging the students, teachers, and parent body. Drought hardy native trees were planted at the school.

Lower Stony Creek

The Stony Creek area is an example of the indigenous vegetation and wildlife that used to exist throughout the Western Plains of Victoria. Recent restoration has raised the profile of the area, and future work will build on the established escarpment shrubland and continue the creation of a habitat corridor along Stony Creek.

Upper Stony Creek

This project involves the transformation of a 1.2 kilometre section of the Upper Stony Creek into a community space with walking paths, wetlands and a revegetated creek bed. The project won the Excellence in Strategic or Master Planning Award at the Stormwater Victoria Awards for Excellence in 2016.

4.5.3 Mornington Peninsula Landcare Biolinks

'Linking the Mornington Peninsula Landscape' (Mornington Peninsula Landcare Network, n.d.) aims to sustain and build the capacity of local groups to implement and maintain on-ground projects that contribute to landscape restoration, connectivity, and environmental sustainability. Using the 'Bay to Bay Biolink' as a model, the project engages a project coordinator, an engagement specialist, and a local ecologist to assist Peninsula Landcare groups to work with residents to produce local biolink plans. The project will be undertaken over five years across the Mornington Peninsula and include Watson Creek Catchment, Sheepwash Creek Catchment, Main Creek Catchment, Southwest Mornington Peninsula Landcare region, Dunns Creek Catchment, Merricks Coolart Catchment, and Red Hill South Landcare region.

4.5.4 Gardens for Wildlife

Launched in 2006, the Knox City Council's Gardens for Wildlife (Knox City Council, n.d.) program was designed to encourage residents to provide habitat and food sources for threatened wildlife (e.g. birds, insects, and frogs), by planting indigenous plants or suitable exotic species in their gardens. The program is a partnership with the Knox Environment Society and currently has over 800 contributing households.

4.5.5 Living Links

The goal of the Living Links project (Living Links, n.d.) is to create a network of green and blue spaces in Melbourne's south-east. The project aims to connect parks, reserves, coast and beaches, rivers, creeks and wetlands. Currently, 17 corridors have been identified with potential connection opportunities to improve the local community and environment.

4.5.6 City of Sydney

The 2013 City of Sydney Urban Forest Strategy (City of Sydney, 2013) is a key tool for delivering on the Sustainable Sydney 2030 (City of Sydney, 2017) and Greening Sydney (City of Sydney, 2012) plans. The city has set the goal of increasing its current canopy cover from 15.5% to 23.25% by 2030 and 27.3% by 2050, and the program also addresses the trees' age spread and species diversity. Key tools for achieving these targets are the Local Environmental Plan (City of Sydney, 2016) and the Development Control Plan (City of Sydney, 2012). The Local Environmental Plan is the key legal document for guiding planning decisions, and the Development Control Plan supports these plans by providing more detailed planning and design guidelines. Important elements of the Development Control Plan are protection tools for existing trees on private property and the requirement for a minimum of 15% canopy cover (within ten years) for all land classes and developments (City of Sydney, 2013). In addition, a landscape codehas also been developed to ensure that developments the support greening goals of the City of Sydney.

4.6 Existing collaborative models in Melbourne

As previously identified, many organisations are undertaking significant work to maintain and enhance our urban forest. While this work is often being undertaken in an isolated and ad hoc manner there are many existing collaborative networks across Melbourne that can provide models of co-ordinated action. A few key models are provided in this chapter.

4.6.1 Association of Bayside Municipalities

The Association of Bayside Municipalities is an unincorporated association of the councils that have frontage to, and are affected by, the tidal influences of Port Phillip Bay.

The Association of Bayside Municipalities is hosted and recognised by the Municipal Association of Victoria as the key representative of local government in relation to the sustainable management and health of Port Phillip Bay. The ABM provides a forum for:

- information exchange, innovation, and best practice in coastal management
- advocacy – representing the collective views of member councils
- networking and collaboration between member councils, other Bay stakeholders and coastal organisations
- leadership in coastal planning and practice
- integrated, whole-of-bay outcomes for Port Phillip Bay

The Association of Bayside Municipalities has a steering committee with elected councillor representation from each member municipality. It is supported by an executive officer who provides secretariat services to the ABM committee and coordinates programs. A technical group, comprising municipal staff, meets on an as-needs basis, and project control groups manage specific actions.

4.6.2 Council Arboriculture Victoria

Council Arboriculture Victoria is an association of Victorian Council Arborists and Tree Managers that promotes the protection and enhancement of our urban forest, including public and private trees. Council Arboriculture Victoria has an executive committee with five position holders, including chairperson, vice chairperson, treasurer, secretary, and minutes secretary.

It also has a general committee, usually comprised of five to ten people. Council Arboriculture Victoria also meets every 2nd month for a general meeting. Issues relevant to the protection and enhancement of the urban forest are canvassed and discussed and guest speakers promoted.

4.6.3 Greenhouse alliances

Metropolitan Melbourne hosts four sub-regional greenhouse alliances, including:

- Northern Alliance for Greenhouse Action
- South East Councils Climate Change Alliance
- Western Alliance for Greenhouse Action
- Eastern Alliance for Greenhouse Action

Alliances have different memberships, operations, and governance models, but their governance structures are formal.

A paper prepared for the 2013 National Climate Change Adaptation Research Facility (Hunt, 2013) conference summarises the benefits of the greenhouse alliances, noting that alliances:

- provide formal mechanisms to give different groups confidence in collaborating on complex issues,
- scale up local issues into broad-ranging strategic contributions through projects and project advocacy, and
- communicate the need for urgent and deep action.

It also notes that the alliances work with their local communities and cooperate across regions as a network on issues of state or national importance. The Executive Officers meet bimonthly to share information and resources and contribute to expanded regional action on climate change. Importantly for local government, they attract funds into the regions from various sources.

4.6.4 Northern Alliance for Greenhouse Action (NAGA)

NAGA is a grouping of nine metropolitan councils. The NAGA governance structure includes an Executive that meets quarterly, with one representative (councillor or senior staff) from each member organisation. Executive working groups draw membership from both the Executive and the Implementation Forum, and discuss finance, advocacy and governance issues in detail to inform the Executive's decision-making processes. The Implementation Forum meets at least bimonthly.

In addition, NAGA's structure includes working groups to allow detailed project management and/or technical discussion and information exchange.

The NAGA Secretariat, which consists of an executive officer and a project manager, supports and resources these governance structures (Figure 16).

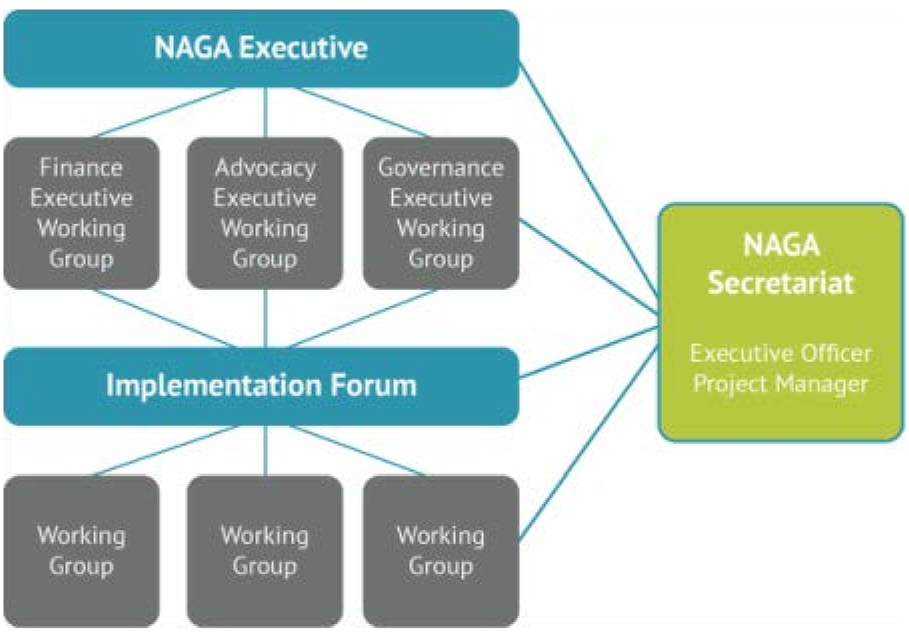


Figure 16 Governance structure of the the Northern Alliance for Greenhouse Action (Source: NAGA Website)

4.6.5 South East Councils Climate Change Alliance (SECCCA)

SECCCA is a network of nine councils in the south-east region that work together to respond and adapt to the impacts of climate change. SECCCA is an incorporated body that follows the Model Rules for Incorporated Associations established by Victoria's Office of Consumer Affairs. The management committee is composed of members nominated by their councils. There are sub-committees that report to the management committee and variously address governance, finance, communications, and projects.

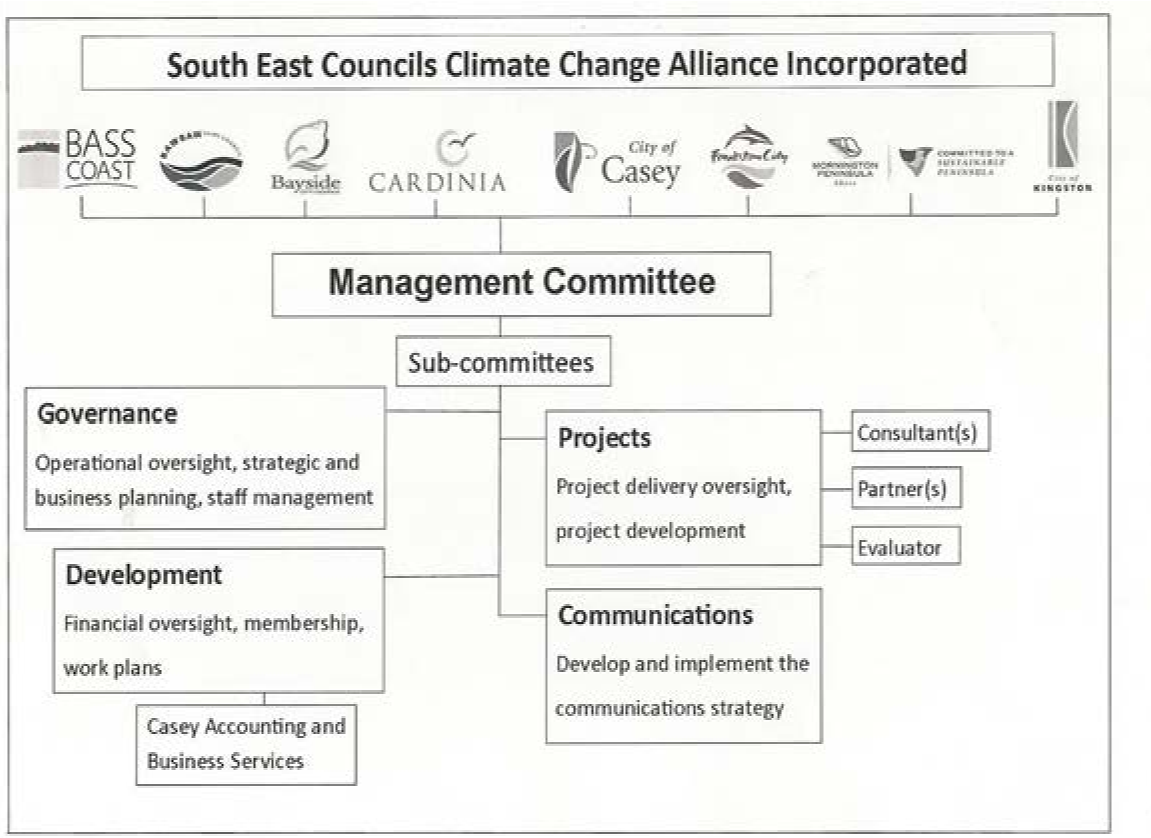


Figure 17 Governance structure for the South East Councils Climate Change Alliance (Source: Hunt 2013)

4.6.6 Western Alliance for Greenhouse Action (WAGA)

The Western Alliance for Greenhouse Action (WAGA) was established in 2006 to bring together interested councils and other organisations committed to a collaborative response to climate change across the region. At present, its members are the eight WAGA councils. Associate members in the past have included Victoria University and the Western Region Environment Centre.

WAGA's governance structure includes a WAGA Executive Committee including one senior manager from each member council. A Chair is elected annually from the committee members and it is responsible for strategic direction, political support, financial contributions and annual budget.

Reporting to this committee is the WAGA Operational Committee which includes operational staff from each member council. The Operational Committee develops WAGA's Annual Implementation Plan and projects for endorsement by the Executive Committee. One of the Operational Committee's most important roles is information-sharing and capacity-building for staff around their corporate climate change programs.

Working Groups are established as required, either lead by an alliance council or by a joint project officer and are accountable to the WAGA Operational Committee. The structure allows for non-WAGA committee members to be co-opted to projects as necessary.

The WAGA Coordinator works with the Operational Committee to develop the Annual Implementation Plan and projects, facilitates the work of the Operational Committee and Working Groups, and is directly accountable to the Executive Committee.

4.6.7 Eastern Alliance for Greenhouse Action (EAGA)

The Eastern Alliance for Greenhouse Action (EAGA) is a formal collaboration of eight councils in Melbourne's east, working together on regional programs that reduce greenhouse gas emissions and facilitate regional adaptation. EAGA operates a similar governance model to WAGA. It includes:

- an executive committee that meets quarterly and manages strategic directions for EAGA's priorities, actions and operations.
- a steering committee that meets monthly and manages projects consistent with the strategic direction
- working groups that meet as required for project implementation and technical discussion

A regional coordinator is employed to support and resource these governance structures.

4.6.8 Greening the West

'Greening the West' is a regional initiative that is about enriching communities in Melbourne's west through the development of green spaces. The alliance of green space advocates forms a steering committee. The steering committee meets quarterly to discuss issues that benefit from collaboration, and to share municipal and joint project updates.

Together they share knowledge, promote, and scale practical solutions in the western municipalities of Brimbank, Hobsons Bay, Maribyrnong, Melton, Moonee Valley and Wyndham.

The group is made up of a total of 23 member organisations, including state government departments and agencies, water utilities, and community groups. It includes the following partners: City West Water, the Urban Development Institute of Australia, Regional Development Australia, Yarraville on the Nose, Western Water, VicRoads, Parks Victoria, Melbourne Water, LeadWest, Friends of Lower Kororoit Creek, the Department of Health and Human Services, the Port Phillip and Westernport Catchment Management Authority and the Department of Environment, Land, Water & Planning.

In 2018, changes to the governance structure were considered to incorporate the steering committee within the structure of LeadWest.

4.6.9 LeadWest

LeadWest is a regional not-for-profit, membership-based organisation that advocates for Melbourne's west. It is an independent company limited by guarantee whose membership includes all six local governments in Melbourne's west, joined by companies and other organisations with substantial operations or interests that are based in the west, including those managing water, energy and telecommunications networks.

LeadWest is governed by a 17-member Board of Directors, comprising:

- Twelve Directors representing local governments that are LeadWest members (currently one each from the cities of Brimbank, Hobsons Bay, Maribrynong, Melton, Moonee Valley and Wyndham)
- Four Directors elected by LeadWest members
- An independent Chair of the Board

The Board is supported by committees overseeing policy priorities and has a Chief Executive Officer and two advocacy projects managers.

4.6.10 LGPro Biodiversity Planning Network Special Interest Group

LGPro is the peak body for Local Government professionals in Victoria. It has a Board comprising 10 people, all of whom are elected by its members every three years. The executive officer provides secretariat services for the Board and is supported by several staff.

LGPro supports its members through a broad range of professional development programs, online learning opportunities, forums, and events. A key aspect of this support program is the professional networks known as Special Interest Groups (SIGs). The SIGs provide opportunities to network, share best practice, and improve practices and knowledge. Each SIG is supported by an online forum.

The Biodiversity Planning Network SIG is primarily for local government staff that implements biodiversity legislation and policies to assist in the protection and enhancement of natural values within their municipality and the State. External attendees are by invitation only. The Biodiversity Planning Network SIG:

- Discusses emerging issues with the aim of providing advice to policy makers, and to advocate for the protection of biodiversity
- Shares knowledge and experience to improve the implementation and outcomes of legislation and policy (e.g. Native Vegetation Framework, local policy)
- Provides an ongoing mechanism and forum for communication, consultation, and liaison with other government agencies and stakeholders on biodiversity issues
- Provides opportunities for professional development, peer support, and communication

The network has regular meetings across two metropolitan regions: the Western & Northern region, and the Eastern & Southern region.

4.7 International activities

4.7.1 Louisville, Kentucky, United States of America

In the United States, Louisville, Kentucky, is one of the cities most susceptible to the urban heat island effect, and it has been ranked fourth in terms of the hottest urban areas (Rice, 2014). In 2015 a detailed canopy assessment was conducted by the Davey Resource Group, which determined canopy cover to have declined from 40% in 2004 to approximately 37% by 2015 (Davey Resource Group, 2015). Much of the remaining cover was in protected parks and not in the city centre, streets, or residential areas. The report predicted that the cover was likely to decline further given that 10% to 20% of the trees were ash and therefore susceptible to emerald ash borer (*Agrilus planipennis*). The consultants produced a map of all realistically plantable areas, along with planting priorities based on their potential impact on mitigating urban heat island effect, stormwater, fragmentation, and population density. A comprehensive study in 2016 (Urban Climate Lab, 2016) assessed the extent of the heating effect and potential impact on the health of residents and established a canopy target of 45%. The report presented both metro-wide and neighbourhood specific recommendations, and tree planting and revegetation were central to these.

4.7.2 Boulder, Colorado, United States of America

Boulder's urban forest and canopy has faced a range of challenges, from EAB through to a series of wild fires and floods. Consequently, a part of the City of Boulder's Resilience Strategy is an urban forest strategy (City of Boulder Colorado , 2016). To aid in the development of this strategy, the city has undertaken a tree inventory, a canopy assessment, and an emerald ash borer review, and it is currently involved in an urban forest strategy public engagement program.

4.7.3 Vancouver, British Columbia, Canada

A review in 2014 found that Vancouver's canopy cover was declining (City of Vancouver, 2014). While in 1995 the canopy cover was estimated to be 22.5%, by 2006 it had fallen to 20%, and by 2013 it had fallen further to 18%. The current urban forest strategy has set a target of growing the canopy cover to 20% by 2030 and 22% by 2050. To achieve this, a range of tools have been implemented, and these include strengthening tree protection and retention by-laws, expanding park planting programs, and creating street management plans.

4.7.4 New York City, New York, United States of America

Cool Neighbourhoods NYC (City of New York, 2017) is a US$106 million program launched in 2017 that aims to minimise the urban heat island effect through strategic street and park tree planting, with a focus on vulnerable neighbourhoods. New York City also calculated that it would be more cost-effective to construct source controls and green infrastructure to manage its stormwater than to continue to increase the capacity of its traditional grey infrastructure. In 2011, the NYC Green Infrastructure Plan (City of New York, 2011), a detailed plan for adopting green infrastructure for water pollution control via watershed planning was launched. The plan included significant funding (US$187 million through to 2015, and US$1.5 billion through to 2030).

4.7.5 City of London, United Kingdom.

The 2014 i-Tree eco analysis of the Greater London urban forest was the largest i-Tree Eco project in the world at the time of its completion (Treeconomics, 2015). The analysis found that there were 8.4 million trees in Greater London, delivering at least £133 million of benefits every year in the form of pollution reduction, carbon sequestration, and stormwater management. Although approximately 60% of the trees were in private ownership, 60% of the ecosystem service benefits were provided by public trees in parks and green spaces due to the size of those trees.

The i-Tree eco data were used to help support the development of the urban forest goals in the London Environment Strategy 2017 (Greater London Authority, 2017). The goals included growing the green cover to 50% by 2050, increasing canopy cover from 20% to 22% by 2050, ensuring adequate protection for existing trees, instigating a major tree planting program, and setting up a data/monitoring system.

4.7.6 Metropolitan Area of Chicago, Illinois, United States of America

Established in 2013, the Chicago Region Trees Initiative is a collaborative effort by 13 regional organisations to develop a strategy for the seven-county metropolitan urban area. The aim is to ensure that the forest population is better understood and valued, that effective performance measurement systems are set up, and most importantly that the forest will be healthier, more resilient, and diverse by 2040.

As part of the strategic development, the initiative will address critical issues such as:

- Data gathering and analysis to better show the underserved and challenged areas
- Increasing tree care and forestry stewardship activities and ability
- Increasing knowledge gaps, risk assessment, and management ability and policy support
- Sharing information and raising the profile of Chicago Region Trees Initiative in the wider community

The strategy will include actionable goals for canopy cover, species and age diversity, and management skills across the public and private spectrum.

4.7.7 Chicago Wilderness Program, Illinois, United States of America

The Chicago Wilderness Program set out in 2004 to map the green infrastructure of seven Illinois counties using geographic information systems, with the goal of identifying critical green infrastructure areas within the region to protect. The most recent version of the project Green Infrastructure Vision 2.0 (Chicago Metropolitan Agency for Planning, n.d.) set out to further collect and refine the data to find significant blocks of unfragmented landscapes, identify assemblages of mix habitats, assess compatible adjacent land/water features, and define habitat connection networks. The goal was to assist with the creation and preservation of a mosaic of biodiversity. These online data are available to an array of decision-makers in the environmental sector, including those involved in urban forestry management. The Chicago Wilderness is now a collaboration of 250 organisations.

4.7.8 City of Guelph, Ontario, Canada

The City of Guelph's Urban Forest Strategy (2009) found that the solution to successfully addressing the challenges facing its urban forest was to elevate the importance of green infrastructure and place it on par with the roads, sewers and buildings. As such, the city's policy needed to define the urban forest as essential green infrastructure and a priority for protection and management. The strategy developed 'tree friendly zoning', a 'tree first' site plan process, and 'tree friendly' urban design and open space guidelines as implementation tools (Urban Forest Innovations Inc., 2009).

4.7.9 The City of Singapore, Singapore

Singapore's first urban greening program began in 1967 with a vision of becoming a 'Garden City.' The aim was to make the newly founded, independent republic a clean and liveable city for its citizens, create an attractive destination for foreign investment and tourism, protect important waterways and water reserves, and aid with regulating the microclimate (Friess, 2016). The primary tool to support this aim was tree planting in new urban areas and along streets (Singapore Government, n.d.). By the 1970s the program had expanded to include the creation of parks and green spaces for recreation and improved air quality, and the 1975 Parks and Tree Act provided the necessary gravitas and stimulus (e.g. large concreted areas had to include 30% to 40% greenery). (Friess, 2016)

The 1992 Singapore Green Plan was Singapore's first environmental strategy and aimed to ensure continued economic growth without environmental compromise. The Plan has been periodically updated to expand its environmental goals (National Library Board Singapore, 2017). In 1998, the 'Garden City' morphed into a 'City in a Garden' with the aim of 'greening' going beyond improving the built environment and living standards to becoming an essential economic contributor (Singapore Government, n.d.), (National Parks, 2004). Since then, a succession of integrated strategic/planning documents has been developed with green infrastructure components that support the 'City in a Garden' vision.

Singapore's limited natural resources have meant that from the outset it has had to be creative and use resources sustainably while generating economic growth (Hean, 2017). Integrated long-term planning, and the government's majority land ownership (Singapore's government owns about 85% of the land (Shatkin, 2014, p. 117), have meant that "urban planning is synonymous with national development" (Shatkin, 2014, p. 116). Urban planning and greening have become an integral part of the country's identity and are a vital tool for delivering high living standards, managing limited water resources, preparing for future threats (e.g. climate change), and contributing to its economic success (through tourism, green technology, and green training) (National Parks, 2017), (Shatkin, 2014), (Ministry of the Environment and Water Resources MEWR, 2015), (Ministry of the Environment and Water Resources (MEWR), 2012), (Ho, 2014).

Due to a lack of natural water and reservoirs, Singapore is considered one of the world's most water-stressed countries (Luo, et al., 2015). The growing population, economic demands, and more recently the impact of climate change on weather patterns are putting constant pressure on the country's water supply. Today, freshwater is provided by 17 man-made reservoirs, a pipeline from Malaysia, water desalination, and wastewater reclamation. Watershed protection, i.e. drainage management into the waterways and reservoirs, has long been part of Singapore's land use planning. As vegetated areas were known to reduce runoff, sediment, and pollutants entering waterways, the forests surrounding the McRitchie Reservoir were designated as a catchment nature reserve as early as the 1860s (Friess, 2016). The first tree planting programs in the 1960s after Singapore had gained independence focussed on watershed protection as a key benefit of the program. The *2001 Sewage and Drainage Act* ensured that the role of vegetation in protecting the watershed was written into law (Friess, 2016). More recently, the implementation of Singapore's 2006 Active, Beautiful, Clean Waters (ABC Waters) programme sought to integrate stormwater drains and canals into the surrounding green infrastructure with the goal of beautifying urban areas, creating blue recreational areas, and importantly improving stormwater quality.

Urban heat island effects were studied in Singapore as early as 1964, and the studies to date have clearly illustrated the considerable difference in temperature that green space can provide (Friess, 2016). Some research has even found differential cooling from different green spaces. The findings also highlight the role of proper land use planning, urban heat island design in high rise buildings, and the use of urban greening (urban forest, green roofs, facades, and vertical building greening). Despite Singapore's growing population and densification, it has managed to grow its canopy cover from 20% in 1987 (Newman, 2014) to close to 30% in 2017 (Choo, 2017).

5 What is the policy, planning and legislative context in Melbourne?

5.1 Introduction

The stewardship and management of the urban forest impacts on a range of diverse disciplines, such as:

- arboriculture services
- town planning
- public open space and conservation reserve management
- traffic engineering
- climate change adaptation and mitigation
- urban and landscape design
- water and waterway management
- aboriginal heritage
- public health
- social policy

This section summarises the key policy frameworks or relevant strategies that, through these disciplines, influence the management of the urban forest. They include:

- Planning policy and the Victoria Planning Provisions
- Sustainable design requirements
- Plan Melbourne 2017–2050
- Protecting Victoria's Environment – Biodiversity 2037
- Water for Victoria
- Yarra River Action Plan *Wilip-gin Birrarung murron*
- Healthy Waterways Strategy 2013–2017
- Climate change framework and climate change adaptation plan
- Victorian Public Health and Wellbeing Plan 2015–2019
- Victorian Memorandum for Health and Nature
- *Aboriginal Heritage Act 2006*

5.2 The planning policy framework

A planning scheme is a statutory document that sets out objectives, policies and provisions for the use, development and protection of land in the area to which it applies. It regulates the use and development of land through planning provisions to achieve those objectives (Department of Environment, Land, Water and Planning , n.d.).

Each of the 79 local government areas in Victoria, including the 32 municipalities of metropolitan Melbourne, is covered by a planning scheme. Planning schemes are legal documents prepared by the local council (or the Minister for Planning) and approved by the Minister.

Planning schemes consist of:

- maps that show how the land is zoned, and overlays affecting the land
- an ordinance that sets out the written requirements of a scheme, including local policies and the types of use or development which needs a permit
- incorporated documents such as codes of practice

Zones indicate the primary character of the land, whether it is residential, industrial, or rural, and determine the types of uses that may occur. Some local areas have special planning controls (known as overlays), such as areas of significant vegetation. These controls are in addition to the zone controls and ensure that important aspects of the land are recognised.

In addition to zones and overlays, other requirements in the ordinance, such as particular provisions, may also apply depending on the proposal for the land. Planning schemes contain state standard provisions drawn from the Victoria Planning Provisions as well as local policy and provisions. State provisions – the Victoria Planning Provisions – include fixed state content and zones, overlays and incorporated documents. The *Planning and Environment Act 1987* (Victorian Legislation and Parlimentary Documents, 2012) distinguishes between the Victoria Planning Provisions (VPP) and a planning scheme. The Victoria Planning Provisions are a comprehensive set of planning provisions for Victoria; they are not a planning scheme and do not apply to any land. Rather, the VPPs are a statewide reference to be used as required to construct planning schemes. VPP also refer to many incorporated documents. Some parts of the VPP, such as state policies, are included in every planning scheme.

Planning scheme content specific to a local area (local provisions) is contained in the Municipal Strategic Statement, local policies, schedules and incorporated documents. The local planning policy content must be provided by the planning authority (usually the local council). It must include a Municipal Strategic Statement (MSS) and select the appropriate zones and overlays from the VPP for inclusion in their planning scheme.

Planning schemes can apply to all private and public land in Victoria. A planning scheme is generally binding on all people and corporations, as well as on every Minister, government department, public authority and local council. Some exemptions apply. These relate to existing use rights, exemptions declared under Section 16 of the *Planning and Environment Act 1987*, Commonwealth land, and permanently reserved Crown land. The administration and enforcement of a planning scheme is the duty of a responsible authority. In most cases that is a local council, but it can be the Minister administering the *Planning and Environment Act 1987* or any other Minister or public authority specified in Clause 61.01 of the scheme. Changes to the planning scheme may be made by both the Minister for Planning and the local council.

5.3 Sustainable design in the Victoria Planning Provisions

5.3.1 Introduction

Victoria's statutory planning system includes regulations that can potentially influence vegetation protection and opportunities to increase or decrease vegetation on private property in residential areas. Broadly, these are (1) residential planning zones, which are subject to (2) residential development standards, and (3) planning overlays. Many municipalities also use local laws as a fourth but perhaps less systematic tool for vegetation protection, particularly to protect significant trees. Enforcement and penalties for not following these regulatory measures remain a real challenge for local governments.

The Victoria Planning Provisions provide the template for residential planning zones and have three clauses that may impact on opportunities for planting vegetation in new developments. These are the new 'garden area requirement', a clause for 'single dwelling on a lot', and a clause for 'two or more dwellings on a lot' (the combined codes are commonly known as Rescode). Municipalities may have additional requirements that impact on vegetation in their schedules to zones. Schedules provide local councils with the opportunity to customise the standard zoning requirements to a specific local context.

Rescode clauses contain several standards that potentially impact on vegetation in residential zones. These can be categorised as requirements that relate to non-built spaces which could accommodate vegetation and built elements that would influence the dimensions of those non-built spaces. Permit applications for lots with 'two or more dwellings' residential zones and those that allow residential uses must also include a landscape layout.

Local councils may add in additional details in schedules in their planning schemes. Residential zones may have schedules that refer to specific geographic areas and may include specific additional requirements which affect vegetation for development proposals for two or more dwellings on a lot.

Overlays are planning controls in addition to planning zones and their schedules and are also specific to defined areas. Only one zone applies to a lot, however it may have multiple overlays. Those that relate to vegetation protection are environmental and landscape overlays, while some municipalities also use heritage overlays to protect significant trees.

Many municipalities have their own local laws, which require applications for permits to remove or carry out works to trees on both public and private property. Significant or exceptional tree registers are local law but also only protect individual trees in an ad hoc manner. Nonetheless, local laws may be an additional protection for trees on private property if that scope is defined by individual councils' laws.

5.3.2 Planning zones and overlays

The Victoria Planning Provisions provide the template for residential planning zones (Clause 32) and have the three Rescode clauses that may impact on opportunities for planting vegetation in new developments. Municipalities may have additional requirements that impact on vegetation in their schedules to zones. Schedules provide local councils with the opportunity to customise the standard zoning requirements to a specific local context.

5.3.3 Garden area requirement

The garden area requirement only applies to two residential zones, the General Residential Zone (GRZ, Clause 32.08) and the Neighbourhood Residential Zone (NRZ, Clause 32.09). Introduced in March 2017, local governments must now assess the garden areas in residential development proposals requiring a planning permit on lots over 400 square metres in those two zones. Garden areas do not include driveways, car parking or built areas but may include patios, swimming pools and tennis courts. Three categories apply:

- Lots between 400 and 500 square metres are required to have 25% of their area set aside as garden area
- Lots between 501 and 650 square metres are required to have 30%
- Lots over 650 square metres are required to have 35%
- The garden area requirement is mandatory and in addition to the performance-based requirements of Clause 54 and 55.

5.3.4 Clauses 54 and 55 – residential development standards

These clauses contain standards that potentially impact on vegetation in residential zones. They are requirements relating to non-built spaces that could accommodate vegetation and built elements and thereby influence the dimensions of those non-built spaces. They include:

- Non-built spaces: front, side and rear setbacks, site coverage, permeability, significant trees, private open space, and communal open space
- Built elements: building height, site coverage, access ways and carparks, storage

For example, both Clause 54 and 55 require that dwellings do not cover more than 60% of a lot (unless a municipality has defined a different standard to its residential zones). Clause 54 – 'one dwelling on a lot' – has 'A' standards that are not defined in a separate document but are incorporated throughout that clause, and Clause 55 has 'B' standards that operate in the same way. Clause 55 also requires that development proposals include a landscape layout for three residential zones: GRZ, NRZ, and the Residential Growth Zone (RGZ, Clause 32.07). This requirement also applies to two other zones, the Activity Centre Zone and Commercial Zone 1, which allow residential uses.

5.3.5 Deep soils requirements for apartment developments

Clause 55.07 sets out requirements for an apartment development. These include a deep soil areas and canopy trees objective 55.07-4 'To promote climate responsive landscape design and water management in developments to support thermal comfort and reduce the urban heat island effect'. This objective includes Standard B38 that the landscape layout and design should:

- Be responsive to the site context.
- Consider landscaping opportunities to reduce heat absorption such as green walls, green roofs and roof top gardens and improve on-site storm water infiltration.
- Maximise deep soil areas for planting of canopy trees.
- Integrate planting and water management.

Clause 58.03 sets out requirements for Site Layout and contains 58.03-5 Landscape objectives that includes in part:

- To encourage the retention of mature vegetation on the site.
- To promote climate responsive landscape design and water management in developments that support thermal comfort and reduces the urban heat island effect.

The Standard D10 includes references to the retention or planting of canopy trees and that developments should maximise deep soil areas for planting of canopy trees.

5.3.6 In addition, the Better Apartments Guidelines developed to support these clauses notes that deep soil areas support canopy trees which improve residential amenity, make neighbourhoods greener and reduce the heatprovides accommodate deep soil areas. the guidance to landscaping Standard D10 supports this section on minimum tree provision, minimum deep soil areas and deep soil locations. Municipality-specific schedules to residential zones

Local councils may add additional details to schedules in their planning schemes. Residential zones may have schedules that refer to specific geographic areas. For example, Banyule City Council has two schedules for its GRZ: Schedule 1 refers to areas that the council 'Accessible areas and Ivanhoe residential diversity areas', and Schedule 2 is for 'Incremental areas.' These areas are spatially distributed throughout the municipality. Moreland City Council has only one schedule for its NRZ, so its requirements apply to any lot in that zone across the municipality.

The schedules to residential zones may include specific additional requirements that affect vegetation in the B13 landscaping requirement of Clause 55 and are therefore only relevant for development proposals for two or more dwellings on a lot. For example, both of Banyule's GRZ schedules require landscape plans that indicate at least one large tree in the front setback, and Schedule 2 has an additional requirement for one tree for every 400 square metres of the lot.

Municipalities that have specific tree requirements in the schedules to their residential zones for development proposals for two or more dwellings are Greater Dandenong (adopted 2013), Banyule (adopted 2014), Stonnington (adopted 2014), Moreland (adopted 2015), Whitehorse (adopted 2015), Brimbank (adopted 2016), Darebin (adopted 2017), and Knox (adopted 2016). Schedule requirements include a minimum number of trees in the total lot, in front setbacks, and in private open space. Specific characteristics of these trees include that they are canopy trees, along with their size, maturity, and species (with Whitehorse noting that trees should preferably be indigenous), and the dimensions of areas to accommodate trees (defined as 'permeable' by Knox City Council).

5.3.7 Planning overlays

Overlays are planning controls that apply in addition to planning zones and are specific to defined areas. While only one zone applies to a lot, it may have multiple overlays. Those that relate to vegetation protection are environmental and landscape overlays, and some municipalities also use heritage overlays to protect significant trees. Of the eleven metropolitan councils that have vegetation-related overlays, most use the Environmental Significance Overlay (ESO), followed by the Vegetation Protection Overlay (VPO). The first is a more general mechanism that requires planning permission for new development on land with environmental constraints and values. The VPO specifically protects vegetation and requires permits for the removal of those plants (with councils able to define specific rules in the schedule to the overlay).

5.3.8 Bushfire Management Overlay (BMO)

The Bushfire Management Overlay is applied to land that may be significantly affected by a bushfire. New development and uses covered by the overlay may require a planning permit. There are also planning permit exemptions that allow vegetation management around properties for bushfire protection. These exemptions are generally known as the 10/30 rule and the 10/50 rule and allow clearing of vegetation without a planning permit. The exemptions do not apply to all municipalites within the *Living Melbourne* metropolitan area.

The 10/30 exemption applies if there is no Bushfire Management Overlay on the property. This means permits are no longer needed to:

- remove trees for up to 10 metres around an existing building (that is used for accommodation)
- clear any vegetation except trees for up to 30 metres from that building

The 10/50 exemption applies if there is a Bushfire Management Overlay on the property. This means permits are no longer needed to:

- remove trees for up to 10 metres around an existing building (that is used for accommodation)
- clear any vegetation except trees for up to 50 metres from that building

Under both the 10/30 and 10/50 rules the building must have existed before September 2009.

Landowners can also clear a maximum combined width of four metres of vegetation an existing property boundary fence between properties in different ownership that was constructed before 10 September 2009.

5.3.9 Local laws

Many municipalities have their own local laws that require permits to remove or carry out works to trees on both public and private property. The City of Frankston's local law adds specific tree size requirements for permits for tree works and protection on private property. Local laws may also define tree protection zones within which, for example, trees should not be affected during construction works. Significant or exceptional tree registers are another type of local law that also only protects individual trees in an ad hoc manner. Nonetheless, local laws may provide additional protection for trees on private property if individual councils define the scope of those laws to include private land.

5.3.10 Building regulations

The National Construction Code sets minimum standards for construction, ensuring that new buildings and alterations, and additions to existing buildings, are safe and meet a minimum acceptable level of health, safety, amenity, and sustainability (The Australian Sustainable Built Environment Council, 2016).

The National Construction Code is a Council of Australian Governments initiative that is managed by the Australian Building Code Board. The National Construction Code sets out the minimum standards for all new building works throughout Australia. It is comprised of the Building Code of Australia and the Plumbing Code of Australia (Volume 3). The Building Code of Australia includes two volumes: Volume 1 applies to multi-residential, commercial, industrial and public buildings (Class 2 to 9), and Volume 2 applies to low rise residential (Class 1) and non-habitable buildings (Class 10).

The overall goal of the NCC is to 'enable the achievement of nationally consistent, minimum necessary standards of relevant safety (including structural safety and safety from fire), health, amenity and sustainability objectives [in the design and construction of new buildings] efficiently.' The specific goal of the energy performance provisions of the NCC is to 'reduce greenhouse gas emissions'.

5.4 Plan Melbourne 2017 – 2050

Plan Melbourne 2017–2050 (Victoria State Government, 2016) is the Victorian Government's long-term plan to accommodate Melbourne's future growth in population and employment. It applies to the 32 local government areas that are impacted by the Urban Growth Boundary. Where relevant, planning and responsible authorities must consider and apply the strategy under Clause 9 of the VPPS. It includes:

- Principles that underpin a long-term vision for Melbourne
- Outcomes to drive Melbourne as a competitive, liveable, and sustainable city
- Directions that set out how these outcomes can be achieved
- Policies outlining how each outcome will be approached, delivered, and achieved

A separate five-year implementation plan has been developed as a companion document to Plan Melbourne 2017-2050. The implementation plan sets out how Plan Melbourne will be delivered and focuses on the short-term actions essential for successful implementation.

Directions, supporting policies, and actions of note in the context of the metropolitan urban forest strategy include:

Direction 2.1 Manage the supply of new housing in the right locations to meet population growth and create a sustainable city

Plan Melbourne 2017–2050 (Victoria State Government, 2016) articulates the benefits of increasing urban density and provides a framework and directions for how and where urban densification should take place. In relation to housing density, Plan Melbourne makes the following policy observations (with emphasis added in *italics*):

- Melbourne will need 1.6 million new homes over the next 35 years. One of the issues that needs to be addressed includes the *provision of medium and higher-density housing close to jobs and services.*
- For Melbourne to become more equitable and accessible, local residents need to have a *choice of housing* within their neighbourhood.
- It is unsustainable to keep expanding Melbourne's outer-urban growth areas. If the city continues to expand, the *natural environment will be impacted*, commute times to employment and services will grow longer, and *socioeconomic disparities across the city will increase*.

Direction 2.1 states that there are social, economic, transport and environmental benefits of creating a more compact, sustainable city. The environmental benefits of higher-density neighbourhoods are that they create opportunities for efficient use of resources and materials, reduce pollution due to the promotion of sustainable transport, preserve and help fund the maintenance of public open space, create new public open space, reduce overall demand for development land, and avoid expanding suburbs without supporting services.

According to the Plan, since 2014 around 70% of all new housing has been built in established areas, and it provides two projections for growth in Scenarios 1 and 2 below (Table 8).

Table 8 Housing distribution between established areas and growth area greenfields (Source: DELWP, Plan Melbourne 2017-2050)

Scenario 1 Victoria in Future 2016			
	Net dwellings additions 2015-51		
Region	Total	Established	Greenfields
Inner metro	215,000	215,000	0
Western	385,000	150,000	235,000
Northern	355,000	175,000	180,000
Inner South East	110,000	110,000	0
Eastern	175,000	175,000	0
Southern	310,000	185,000	125,000
Total Melbourne	1,550,000	1,010,000	540,000
	100%	**65%**	**35%**
Scenario 2 Aspirational scenario			
	Net dwelling additions 2015-51		
Region	Total	Established	Greenfields
Inner metro	230,000	230,000	0
Western	365,000	160,000	205,000
Northern	340,000	180,000	160,000
Inner South East	125,000	125,000	0
Eastern	190,000	190,000	0
Southern	300,000	195,000	105,000
Total Melbourne	1,550,000	1,080,000	470,000
	100%	**70%**	**30%**

As such, Plan Melbourne seeks to locate at least 65% of new housing in established areas, and no more than 35% in growth areas, in line with current levels of development and Victoria in Future projections. To achieve this, new development should be directed to areas with appropriate infrastructure, and greater density is supported *where it optimises the value of existing infrastructure*.

However, rather than promoting medium to higher density development across the board, development in growth areas needs to move away from uniform-sized housing lots towards providing both higher and lower density options within each precinct. Additionally, planning for growth areas must deliver a variety of lot sizes and housing types, which can be achieved through:

- larger lots (to provide a sizeable backyard for those families that desire it), and
- options to locate townhouses, low-rise apartments, and aged-care housing close to shopping centres and community facilities.

Direction 5.4 Deliver local parks and green neighbourhoods in collaboration with communities

Direction 5.4 with its attendant policies, 5.4.1 and 5.4.2 addresses greening neighbourhoods, including supporting local open spaces, community gardens and productive streetscapes

Policy 5.4.1 Develop a network of accessible, high-quality, local open spaces

Policy 5.4.2 Support community gardens and productive streetscapes

Direction 6.4 Make Melbourne cooler and greener

Direction 6.4 states: 'To mitigate the impacts of increased average temperatures, Melbourne needs to maintain and enhance its urban forest of trees and vegetation on properties lining transport corridors, on public lands, and on roofs, facades and walls.'

Policy 6.4.1 Support a cooler Melbourne by greening urban areas, buildings, transport corridors and open spaces to create an urban forest

Action 91 Whole-of-government approach to cooling and greening Melbourne

Create urban forests throughout the metropolitan area by:

- Assembling and disseminating spatial data on the green space network, existing tree cover, and surfaces. This data will be the baseline for modelling future greening strategies and their impacts on amenity of our urban areas, including cooling effects.
- Working with local government to establish greening targets for each of the metropolitan regions.
- Liaising with water corporations to identify opportunities for use of alternative water supply to support greening strategies.
- Supporting development of municipal urban forest strategies using a coordinated approach with VicRoads, private road operators, and other public land owners and managers.
- Preparing greening strategies for state-owned public land, including schools, parkland, road, rail, and utility corridors, achieving an appropriate balance between asset protection and urban greening.
- Investigating a targeted grants program to support innovation and actions for greening neighbourhoods.
- Investigating demonstration projects including green roofs, green walls, and landscapes.
- Preparing new guidelines and regulations that support greening new subdivisions and developments via landscaping, green walls, and green roofs, and increase the percentage of permeable site areas in developments.

Direction 6.5 Protect and restore natural habitats

Direction 6.5 states: 'Government and community groups need to work in partnership to map Melbourne's network of green spaces, investigate where the network could be improved, and support the development of the metropolitan urban forest strategy.'

Policy 6.5.1 Create a network of green spaces that support biodiversity conservation and opportunities to connect with nature

The implementation plan notes under 'Initiatives underway' that there are a range of programs and projects such as Living Links, Greening the West, and other initiatives by the People and Parks Foundation that are growing Melbourne's network of green spaces. The *Living Melbourne* brings these initiatives together as part of a metropolitan urban forest strategy for all of Melbourne.'

Action 93 Metropolitan open space strategy

Prepare a metropolitan open space strategy that enhances recreation, amenity, health and wellbeing, species diversity, sustainable water management, and urban cooling across Melbourne. The strategy will include measures to:

- Protect and enhance existing open spaces, underpinned by improved and accessible spatial data.
- Plan for an increase in open space, particularly in areas identified as lacking access to open space, areas undergoing substantial population growth, and areas where the network of green spaces could be expanded or improved.
- Enhance the role, function, and overall community value of currently underutilised public land assets (e.g. utility easements, school grounds) in contributing to the open space network. Further discussion of open space can be found on page 97.

5.5 Protecting Victoria's Environment – Biodiversity 2037

Protecting Victoria's Environment – Biodiversity 2037 (State of Victoria Department of Environment, 2017) is the Victorian Government's plan to stop the decline of biodiversity and achieve overall biodiversity improvement over the next 20 years. It makes the case for increased effort, and defines a new approach to managing biodiversity. The science underpinning the plan seeks to get on top of the problem of Victoria's biodiversity decline and establishes a long-term vision and defines goals. To deliver on these goals, specific targets have been developed.

The Biodiversity Plan presents a long-term vision for Victoria's biodiversity, supported by two goals:

- 'Victorians value nature', and
- 'Victoria's natural environment is healthy'.

The plan sets statewide targets for both goals (Table 11).

***Table 11 Vision, Goals and Targets from Protecting Victoria's Environment – Biodiversity 2037* (State of Victoria Department of Environment, 2017)**

<table>
<tr><td colspan="2">VISION: Victoria's biodiversity is healthy, valued, and actively cared for</td></tr>
<tr><td>GOAL: 'Victorians value nature'</td><td>GOAL: 'Victoria's natural environment is healthy'</td></tr>
<tr><td>Targets:
By 2037:
All Victorians are connecting with nature.
Five million Victorians are acting to protect the natural environment.
All Victorian Government organisations that manage environmental assets contribute to environmental-economic accounting.</td><td>Targets:
A net improvement in the outlook across all species by 2037, so that:
No vulnerable or near-threatened species will have become endangered.
All critically endangered and endangered species will have at least one option available for being conserved ex situ or re-established in the wild (where feasible under climate change) should they need it.
We achieve a net gain of the overall extent and condition of habitats across terrestrial, waterway and marine environments.</td></tr>
</table>

Supporting these targets are 20 priorities that are discussed and expanded upon in the plan. Of relevance to the metropolitan urban forest strategy are Chapters four and five.

Chapter 4 A healthy environment for healthy Victorians

Key points:

- A healthy environment is fundamental to a healthy society.
- More needs to be done to enable Victorians to access nature, including increasing people's awareness and understanding of the environment and how they can act to protect it.
- We all need to work together – across government, business, and the community – to ensure that we have a healthy environment to support a healthy society.

Priority 4 - increase opportunities for all Victorians to have daily connections with nature.

Initiatives by the government to deliver this priority will include:

- Establish reliable baseline information about Victorians' current connection with the natural environment.
- Identify less engaged groups, and understand barriers to engagement to increase opportunities to connect with nature.
- Implement and promote programs to increase opportunities for people to connect with nature, including programs to get Traditional Owners out on Country.
- Promote opportunities for additional 'greening' in established urban areas through broadening standards for public open-space planning provisions in the context of long-term change in population and community needs.

Chapter 5 Linking our society and economy to the environment

This chapter emphasises that the State's natural capital enhances Victoria's ability to generate wealth. It notes that the Victorian Government is planning to integrate the United Nations System of Environmental-Economic Accounting (SEEA) into reporting, decision making, and evaluation of social, economic and environmental outcomes and trade-offs. This will ensure that a form of environmental-economic accounting is used that will help to reveal the linkages between natural capital, society and the economy, and identify risks and opportunities for Victoria. The plan also highlights that Victoria will increasingly need to protect and utilise its environmental assets to deliver co-benefits for the economy and environment, and to help communities become more liveable, resilient, and climate-adapted.

In reference to creating more liveable and climate-adapted local communities, Biodiversity 2037 notes that:

> *'In recognition of the benefits provided by green infrastructure, local governments are planting urban forests and using integrated water management to cool built-up environments by reducing the urban heat island effect, while also removing harmful air pollutants, filtering water, and providing opportunities for people to connect with nature, particularly where native plants are used. Resilient Melbourne, Greater Melbourne's first resilience strategy developed as part of the 100 Resilient Cities Program, aims to ensure a viable, sustainable, liveable, and prosperous city long into the future, and to enable strong natural assets and ecosystems alongside a growing population.*
>
> *Currently, there is no clear 'ownership' of green infrastructure, so green infrastructure projects have historically been conducted opportunistically rather than strategically. Local governments are now leading the way in urban greening, but a whole-of-government approach is needed to ensure the broad range of benefits are realised'. (p. 32)*

Priorities and initiatives arising from this chapter include:

Priority 6 - Embed consideration of natural capital into decision making across the whole of government, and support industries to do the same.

Initiatives by the government and partners to deliver this priority will include:

- In the short term, prepare and publish a set of environmental accounts for the department and portfolio partners and contribute to relevant national initiatives.
- In the longer term, integrate the system of environmental-economic accounting into reporting across the whole-of-government, and into decision making and evaluation of social, economic and environmental outcomes and trade-offs.
- Partner with the broader business community and industry leaders to promote the increased adoption of environmental-economic accounting.

Priority 7 - Help to create more liveable and climate-adapted communities.

Initiatives by the government and partners to deliver this priority will include:

- Use environmental-economic accounting business applications to help government, industry and communities understand the benefits of protecting environmental assets in both the built and natural environments.

- Develop guidelines or standards to give government, industry and communities an increased ability to better realise the benefits of green infrastructure.
- Provide information that enables communities to plan for climate change, compare trade-offs, and create a vision for their region that delivers a strong regional economy and a healthy natural environment.
- Improve the liveability of Victorian cities and towns – for example, by implementing Plan Melbourne 2017–2050.

Priority 8 - Better care for and showcase Victoria's environmental assets as world-class natural and cultural tourism attractions.

Initiatives by the government and partners to deliver this priority will include:

- Work in collaboration with the community to ensure that Victoria's iconic natural assets keep offering opportunities to connect with nature, and provide support to local economies.
- Develop policies and approaches to ensure that tourism to sensitive areas is sustainable and its impacts are minimised.
- Build on existing work to promote Victoria's environmental assets at statewide, regional and local levels as world class natural and cultural tourism attractions.
- Continue to provide world class nature-based experiences through Zoos Victoria, Museum Victoria, Parks Victoria, the Royal Botanic Gardens Victoria, Philip Island Nature Park, and alpine resorts.

5.6 Water for Victoria

The State of Victoria's Department of Environment, Land, Water and Planning 2016 Water for Victoria strategy (Victoria State Government. Department of Environment, Land, Water and Planning, 2016) is the Victorian Government's strategy for the long-term management of Victoria's water supplies. It sets out the following vision:

'*Water is fundamental to our communities. We will manage water to support a healthy environment, a prosperous economy, and thriving communities, now and into the future'.*

The strategy clearly recognizes the two challenges of climate change and population growth, both of which are central to the management of Melbourne's urban forest. It stresses that Victoria is becoming warmer and drier, and that, as the fastest growing state in Australia, Victoria's population is projected to reach 10.1 million by mid-century. Climate change means that Victoria can expect more extreme weather events including droughts, floods, and heatwaves. It also means that, by 2065, annual streamflows to some catchments could reduce by around 50%, resulting in less available water storages.

The strategy identifies 15 projects:

1. Yarra River as a priority waterway for long-term investment
2. Yarra River Protection Project (Birrarung)
3. 2015 Environmental Water Recovery Targets for the Werribee and Maribyrnong Rivers
4. Aboriginal Water Program – mapping Wurundjeri cultural values on the Yarra River
5. Invest $16 million in Werribee and Bacchus March irrigation modernisation
6. $300,000 Federal Government funding for the Coldstream Recycled Water Pipeline feasibility study

7. $91,500 Federal Government funding – South East Melbourne Regional Water Plan pre-feasibility study
8. Reactivate Target 155 for Melbourne
9. South central Victoria market trial
10. Green priority spaces for community health and wellbeing using stormwater and recycled water
11. Better designed suburbs and new developments to support liveable communities
12. Integrated water management forums for Werribee, Maribyrnong, Yarra, Dandenong and Westernport
13. Improved planning arrangements linking to Plan Melbourne and the Yarra River Protection Project
14. Commence long-term water resource assessment for southern Victoria in 2018
15. Review the Central Region Sustainable Water Strategy in late 2016

5.7 Yarra River Action Plan *Wilip-gin Birrarung murron (2017)*

The Yarra River Action Plan (Victorian State Government, Department of Environment, Land, Water & Planning , 2017) outlines Victorian Government's response to the Yarra River Protection Ministerial Advisory Committee (Yarra MAC) Discussion Paper, Protecting the Yarra River (Birrarung). The health of the Yarra River, its tributaries and riparian vegetation is critical for sustaining Melbourne's urban forest. The plan is guided by five objectives:

1. A healthy river
    - *Wilip-gin Birrarung murron* (keep the Birrarung alive)
    - protect and improve the health of the river and its riparian ecology
    - increase the resilience of the river to the impacts of climate
    - change and population growth
    - protect the health of Port Phillip Bay

2. The Great Yarra Parklands
    - recognise the network of parklands along the Yarra as part of the one integrated living whole natural asset
    - improve community access to, and movement along and on, the river
    - increase opportunities to enjoy the river parklands for people of all ages and abilities
    - create more destinations and improve visitor experiences

3. A culturally diverse riverscape
    - in partnership with Traditional Owners, recognise, protect and promote both intangible and tangible cultural values
    - recognise, protect, and promote heritage values
    - quality public places for recreation, celebration and coming together

4. Securing the Yarra footprint

- protect iconic and naturalistic river landscapes from inappropriate development
- connect communities and places along the river with trails and cycling corridors
- recognise the importance of the river to the economic prosperity and vitality of Melbourne and the Yarra Valley

5. Modern governance

- provide visionary leadership and a long-term commitment to delivering the vision and its goals
- partner with the Traditional Owners in the management of natural resources
- align the activities and decisions of responsible agencies and councils
- prioritise collaborative community processes

These objectives are supported by 30 actions. The key actions will be to:

- establish a new Ministerial Advisory Council with a membership that includes experts, stakeholder group representatives, and at least two Wurundjeri Council representatives
- establish Melbourne Water as the lead agency for developing and coordinating implementation of a Yarra Strategic Plan
- coordinate funding to ensure the Yarra Strategic Plan is properly resourced
- require independent auditing and reporting on the implementation of the Yarra Strategic Plan
- establish regular reporting on the environmental condition of the Yarra River and its parklands
- translate the names of geographical sites along the Yarra into the Traditional Owner language

5.8 Healthy Waterways Strategy 2018–28

The Healthy Waterways Strategy 2018-28 (Melbourne Water, 2013) is a shared strategy across Melbourne Water, state and local government, water corporations and the community for the rivers, creeks, estuaries and wetlands of the Port Phillip and Westernport Region. The Port Phillip and Westernport region has a total area of almost 13,000 km^2 extending from Lancefield and Whittlesea in the North to Ballan in the West, Warburton and Drouin in the East and Werribee, Frankston and Cowes in the South. The Strategy has been collaboratively developed with over 630 individuals and 220 organisations, including Traditional Owners from the Wurundjeri Land and Compensation Cultural Heritage Council Aboriginal Corporation, the Bunnarong Land Council Aboriginal Corporation and the Wathaurong Aboriginal Corporation.

The Strategy provides a single framework to protect and improve the waterways' environmental, social, economic and cultural values to the community and meet the obligations for waterway and stormwater management, as outlined in relevant State, national and international legislation, policy and agreements. The Strategy sets:

- A long-term vision for the region:

  Healthy and valued waterways are integrated with the broader landscape, and enhance life and liveability. Waterways connect diverse and thriving communities of plants and animals; provide amenity to urban and rural areas, and engage communities with their environment; and are managed sustainably to enhance environmental, economic, social and cultural values.

- A 50-year vision and a set of 20-50 year goals for each of the five major catchments in the region: Werribee, Maribyrnong, Yarra, Dandenong and Westernport.

- 10-50 years targets for the nine key values that have been chosen as representative measures and their 21 underpinning waterway conditions. These targets are set at the sub-catchment, estuary and wetland levels. The six key environmental values are fish, frogs, macroinvertebrates, platypus, vegetation and birds. The three key social values are amenity, recreation and community connection.
- 45 ten-year regional performance objectives for cultural values, economic values, responding to climate change, responding to urban stormwater and the pressures of urbanisation, community place-making, managing pollution, rural and agricultural activities, litter, vegetation management, controlling pest plants and animals, governance, engaged and knowledgeable community and stakeholders, monitoring, evaluation, reporting and adaptive management.
- Over 900 ten-year sub-catchment, estuary and wetlands performance objectives, that cover areas such as stormwater and water quality, access, recreation, habitat and water for the environment.

The Healthy Waterways Strategy prioritises and aligns effort and investment at catchment and sub-catchment levels to ensure they contribute to broader, regional goals and outcomes. The Strategy contributes to thriving communities that are resilient and connected through nature in many of its approaches and objectives. These include:

- Recognising that the waterways of the region play a growing role in the provision of green open spaces for a growing population.
- Creating cooler, greener and more liveable urban environments through revegetation and as part of managing excess stormwater. Key related ten-year performance objectives of the Strategy include:
    - revegetating an additional 1,888 kilometres of canopy cover alongside waterways
    - maintaining 1,352 kilometres of high and very high quality vegetation and 3,620 kilometres of continuous vegetated buffers
    - reusing an additional 83GL per year of stormwater - which will represent a large source of alternative water for fit-for-purpose use such as irrigating green spaces
    - infiltrating an additional 23 GL per year of stormwater- which will keep more water in the landscape and soils
    - increasing access to and along waterways by 179 kilometres.
- Protecting headwaters to ensure they are retained as features in the landscape for environmental, social, cultural and economic benefits.
- Building capacity to encourage organisations and individuals to contribute to a knowledge collective, share resources, capability, skill, and leverage each other’s efforts.
- Developing environmental-economic accounts for the region’s waterways to demonstrate returns on catchment and waterway investment and better reflect the values provided by waterways in decision-making.
- Better understanding and tracking the multiple benefits of waterway investments, and use this knowledge to collaborate across organisations to achieve improved amenity, recreation and community connection.

- Using a place-based approach to reinvigorate waterways and the land around them, thereby enhancing the health and wellbeing of local communities and flora and fauna. An example of this is the transformation of modified waterways to create more natural, community-loved spaces.
- Protecting and enhancing sites of biodiversity significance
- Conducting a robust multidisciplinary research program that covers liveability, community engagement, and social research; stormwater management and flooding; water quality; streamside vegetation and instream habitat; wetlands and estuaries.
- Protecting existing and restoring habitats through the removal of fish barriers, investigating and mitigating the risk of erosion, investigating options to make more water available for environmental flows or protecting refuge reaches.

5.9 Climate change framework and climate change adaptation plan

5.9.1 Victoria's Climate Change Framework

Victoria's Climate Change Framework (Department of Environment, Land, Water & Planning, 2016) articulates the Victorian Government's long-term vision and approach to climate change. The framework sets out:

- a vision for a net zero emissions, climate-resilient Victoria in 2050
- how action on climate change aligns with jobs, cost of living, and health
- the steps to be taken to commence the transition
- the challenges to be addressed to move to a net zero emissions economy
- how Victoria is preparing for a changing climate

5.9.2 Victorian Climate Change Act 2017

On 23 February 2017, the *Climate Change Bill* passed through the Victorian Parliament, creating a new *Climate Change Act*. The *Climate Change Act 2017:*

- establishes a long-term emissions reduction target of net zero by 2050
- requires five yearly interim targets to keep Victoria on track to meet the long-term target
- introduces a new set of policy objectives and an updated set of guiding principles to embed climate change in government decision making
- requires the government to develop a Climate Change Strategy every five years to set out how Victoria will meet its targets and adapt to the impacts of climate change (from 2020)
- requires adaptation action plans for key systems that are either vulnerable to the impacts of climate change or essential to ensure Victoria is prepared (from 2021)
- establishes a pledging model to reduce emissions from government's own operations and from across the economy (from 2020)
- establishes a system of periodic reporting to provide transparency and accountability, and ensure that the community remains informed.

The *Act* commenced operation in November 2017 and sits alongside other key Victorian Government energy and climate change initiatives, including Victoria's Climate Change Framework, Victoria's Climate Change Adaptation Plan 2017-2020, and the Victorian Renewable Energy Targets (VRET).

5.9.3 Victoria’s emissions reduction target

The Victorian Government has committed to a long-term target of net-zero greenhouse gas emissions from Victoria by 2050. This will be achieved by reducing greenhouse gas emissions as far as possible and offsetting any remaining emissions through activities such as tree planting. Interim targets are to be set every five years to 2050.

Victoria’s renewable energy targets (VRET) are that:

- at least 25% of the state’s electricity comes from Victorian-built renewable generation by 2020, and
- at least 40% of its electricity is renewably generated by 2025.

Delivered by Sustainability Victoria, TAKE2 is the state’s collective climate change program, supporting individuals, government, business, and other organisations to help our state achieve net zero emissions by 2050. The Victorian Government has two pledges:

1. Operational pledge – that Victorian Government departments will take action to reduce operational emissions including energy use, transport and waste, and find cleaner, greener ways to operate. This will contribute to one whole-of-government pledge.
2. Sector pledges – that Victorian Government policies and programs promote lower emissions across the state’s economy in key sectors, including energy, agriculture, transport, and waste.

The Victorian Government also invites voluntary pledges being made by local governments, businesses, community groups and individuals to reduce their emissions and contribute to meeting Victoria’s emissions reduction targets.

5.9.4 Victorian Climate Change Adaptation Plan 2017–2020

The Adaptation Plan (Victoria State Government Department of Environment, Land, Water and Planning, 2017) sets out the Victorian Government’s priorities for leading and supporting the community to adapt to climate change from 2017 to 2020.

It explains how the Government will support adaptation and coordinate action on different scales (local, regional, and sectoral). It also outlines how the Government is already addressing adaptation and lays out the Government’s plan for strengthening these mechanisms and filling important gaps. The Government’s priorities over the life of the Adaptation Plan are to:

- More effectively manage risks to the Government’s own assets and services from climate change by assessing the Government’s current capabilities and practices and addressing whole-of-government risks and impacts in a more coordinated way.
- Help the community to understand and manage the risks and impacts of climate change
- Encourage adaptation action across all policy areas and sectors of the economy by strengthening the consideration of climate change in the policy and regulation of health and human services, emergency management, the natural environment, agriculture, water and the built environment, as well as introducing a new sector-based approach to adaptation planning in preparation for sectoral Adaptation Action Plans under the proposed new legislative framework.

The adaptation plan reiterates the six broader goals:

- Leadership
- Collaboration and shared responsibility
- Connected, resilient, and safe communities
- A healthy environment
- Priority support for vulnerable communities
- A flexible and prosperous economy

5.10 Victorian Public Health and Wellbeing Plan 2015–2019

The vision of the Victorian Public Health and Wellbeing Plan 2015–2019 (Victorian State Government , 2015) is for a Victoria free of the avoidable burden of disease and injury so that all Victorians can enjoy the highest attainable standards of health, wellbeing, and participation at every age.

The Plan outlines the Victorian Government's key priorities to improve the health and wellbeing of all Victorians, particularly the most disadvantaged. As many chronic diseases and injuries are preventable, the plan focuses on supporting healthy living from the early years and throughout life.

The importance of maintaining healthy environments is also a focus of the Plan, as is responding to the impacts of climate change on people's health and wellbeing. The Plan emphasises improving health and wellbeing via a range of public health approaches. These are:

- supporting healthy and sustainable environments, which is critical to the health and wellbeing of the current and future generations. Particular attention is given to climate change adaptation and air, food, and water quality.
- place-based approaches, which emphasise the significance of location to health and focus on a range of settings in which people spend their time.
- people-centred approaches, which focus on building strong partnerships between health services and other networks, and emphasise prevention, empowerment, education, and health literacy.

5.11 Victorian Memorandum for Health and Nature

In April 2017, the Minister for Health and the Minister for Energy, Environment and Climate Change jointly signed a memorandum on health and nature (Victorian State Government Department of Environment, Land Water and Planing , n.d.). The memorandum highlighted the current health issues facing communities and the role that nature has in mitigating their impact. Victoria's parks, open spaces, waterways and green urban spaces provide many benefits, including physical, psychological, social and cultural well-being. These benefits are acknowledged in key policy platforms such as the Victorian Public Health and Wellbeing Plan 2015–19, and Protecting Victoria's Environment: Biodiversity 2037. There are many opportunities to expand activities in this area via collaboration with the health sector, environment, and parks, business, research, planning, and policy to expand impactful nature in our cities. The Victorian Government is committed to supporting health and nature programs.

5.12 Aboriginal Heritage Act 2006

The *Aboriginal Heritage Act 2006* acts primarily to provide for the protection of Aboriginal cultural heritage in Victoria. The *Aboriginal Heritage Regulations 2007* give effect to the *Act*. The *Regulations* prescribe standards, set out the circumstances in which a Cultural Heritage Management Plan should be prepared, and sets the fees for an application for a cultural heritage permit. The *Regulations* should be read in conjunction with the *Act*.

This act allows several different organisations, groups, and bodies to connect and better enforce and preserve policies regarding Aboriginal Heritage. It does this through:

- the establishment of a Victorian Aboriginal Heritage Council to provide a state-wide voice for Aboriginal people, and to advise the Minister for Aboriginal Affairs on issues relating to the management of cultural heritage
- the introduction and management of a system of Registered Aboriginal Parties that allows for Aboriginal groups with connections to country to be involved in decision making processes around cultural heritage. There are three Registered Aboriginal Parties applicable to metropolitan Melbourne – the Bunurong Land Council Aboriginal Corporation, Wathaurung Aboriginal Corporation (trading as Wadawurrung (Wathaurung)), and the Wurundjeri Land and Compensation Cultural Heritage Council Aboriginal Corporation (Wurundjeri).
- raising public awareness and understanding of Aboriginal cultural heritage in Victoria
- establishing an Aboriginal Cultural Heritage Register to record Aboriginal culture
- the establishment of cultural heritage management plans and cultural heritage permit processes to manage activities that may impact Aboriginal cultural heritage. Where areas are identified that may impact on Aboriginal cultural heritage, it is important to engage early and often to both seek the hopes, wants, and desires of the Traditional Owners and to ensure that works at each location are tailored to take account of particular local conditions.
- a system of cultural heritage agreements to support the development of partnerships around the protection and management of Aboriginal cultural heritage
- providing appropriate sanctions and penalties to prevent harm to Aboriginal cultural heritage
- clearer powers for Authorised Officers and Aboriginal Heritage Officers, and increased

5.12.1 Registered Aboriginal Parties

Registered Aboriginal Parties (RAPs) are organisations that hold decision-making responsibilities under the *Aboriginal Heritage Act 2006* for protecting Aboriginal cultural heritage in a specified geographical area. The Victorian Aboriginal Heritage Council determines which applicants will be registered as RAPs. Figure 20 provides a map of the Registered Aboriginal Parties. There are currently 11 RAPs in Victoria, listed in alphabetical order below:

- Barengi Gadjin Land Council Aboriginal Corporation
- Bunurong Land Council Aboriginal Corporation
- Dja Dja Wurrung Clans Aboriginal Corporation
- Eastern Maar Aboriginal Corporation
- Gunaikurnai Land and Waters Aboriginal Corporation
- Gunditj Mirring Traditional Owners Aboriginal Corporation
- Martang Pty Ltd
- Taungurung Clans Aboriginal Corporation
- Wathaurung Aboriginal Corporation
- Wurundjeri Land and Compensation Cultural Heritage Council Aboriginal Corporation
- Yorta Yorta Nation Aboriginal Corporation

These RAPs currently cover approximately 60% of Victoria. Three of these Registered Aboriginal Parties have decision making powers under the *Aboriginal Heritage Act 2006* including the Bunurong Land Council Aboriginal Corporation, the Wathaurung Aboriginal Corporation, and the Wurundjeri Land and Compensation Cultural Heritage Council Aboriginal Corporation.

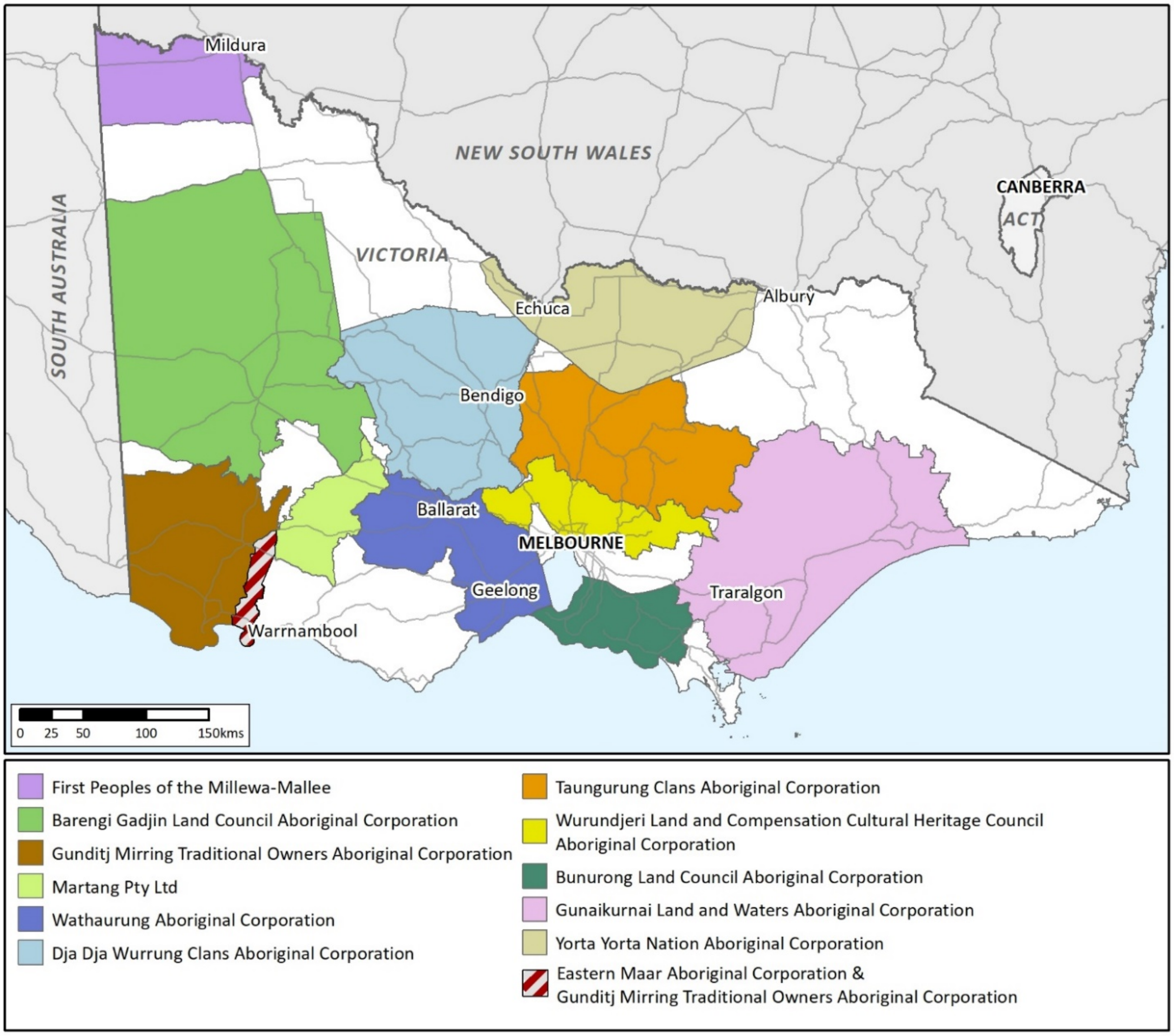


Figure 18 Registered Aboriginal Parties in Victoria

(Source: DELWP https://www.vic.gov.au/system/user_files/Documents/av/Statewide_Appointed_RAPs-wv-23MAR18_150dpi.pdf)

5.13 Melbourne's Open Space

Melbourne's reputation as one of the world's most liveable cities stems from a history of integrated urban planning that has viewed open space as central. Open space reflects what we value and how we live. An example of early planning for open space for a growing city can be seen in Figure 19. This critical green infrastructure includes our parks and gardens, our walking and cycling trails, beaches and foreshores, piers and jetties, and our plazas and civic areas.

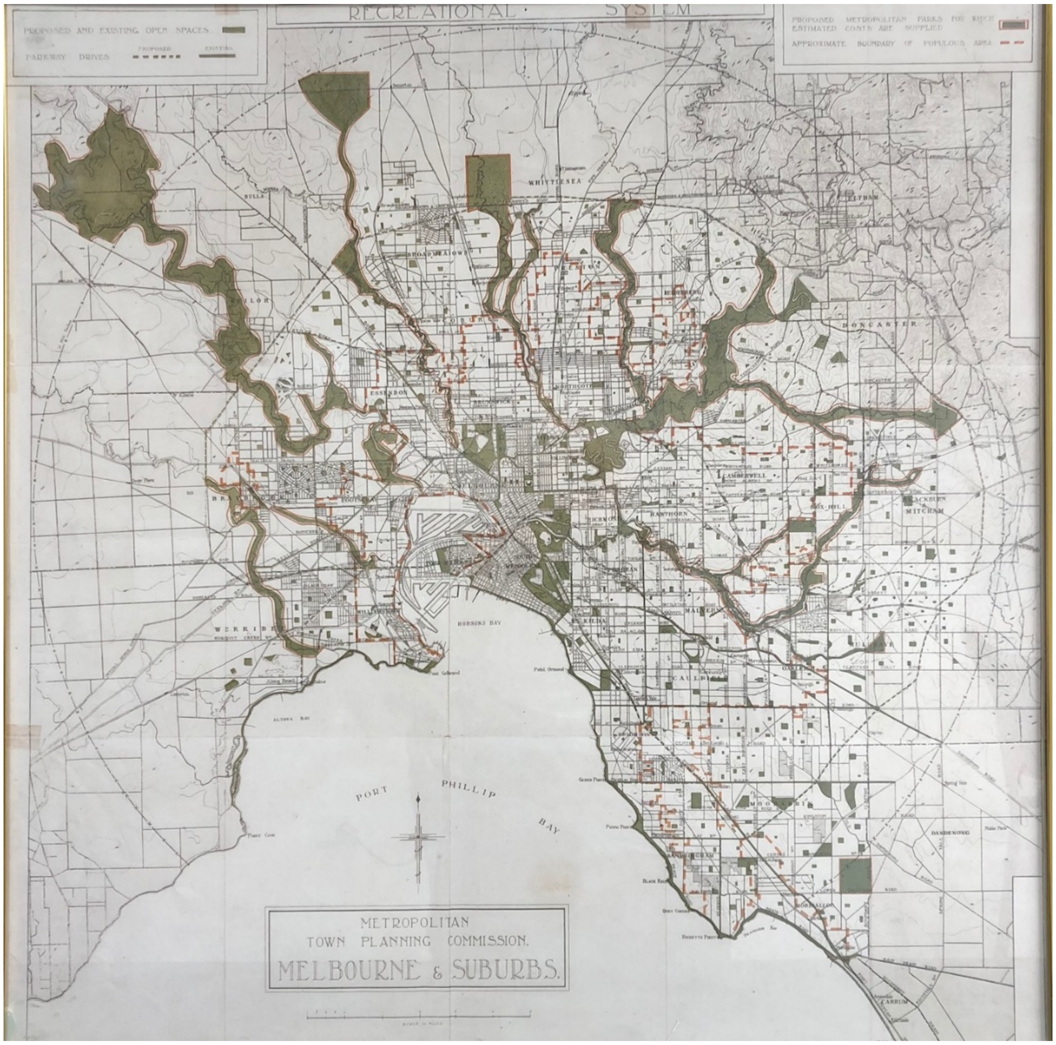


Figure 19 Metropolitan Town Planning Commission open space map 1929

Plan Melbourne 2017-2050 (Victoria State Government, 2016) identified the need for a new generational open space plan for metropolitan Melbourne, and this work is now underway. The new open space plan will guide investment in open space development in partnership with 32 local governments that manage just over 50% of the public open spaces. The intention is to correct some of the current inequities in provision and access to open space across our suburbs, and to tackle the escalating heat island and broader sustainability issues. The plan will look at where investment in existing open space could optimise its use and relevance for a multicultural and aging community, and examine how improvements in design and quality can make more of what we have. This will include reviewing existing and surplus public land to see how it might be repurposed. A further consideration will be where land should be reserved for future generations, its governance, and the onging funding of open space.

The remainder of this section provides some basic analysis of the spatial distribution and area of Melbourne's open space assets. This analysis is based on the information available through the Victorian Planning Authority's **Metropolitan Open Space Network Portal**.

Public land, including the street and road network, constitutes an important component of the urban forest. As a public asset, the majority of this land is managed and maintained by local and Victorian government authorities. As a result, because of the discrete number land managers, the proportion of total vegetation and total tree canopy can be more easily influenced on public land than it can on private land. The public land data have been broken down by total municipality, and for the area inside the urban growth boundary, as per the Victorian Environmental Assessment Council's (VEAC) Metropolitan Melbourne Investigation (2011). As noted in the VEAC report, the proportion of public land managed by local government in comparison to other agencies changes substantially once the urban growth boundary is taken into consideration. The following three tables provide an analysis.

- Table 12 provides a breakdown of open space by category and ownership for the total metropolitan area and as a proportion within the urban growth boundary. It indicates that the total amount of open space across all 32 municipalities is 33%. This figure drops to 19% within the urban growth boundary. There are significant differences in both the proportion of open space by category and ownership when the urban growth boundary is considered, and this affects the management influence that can be exerted.
- Table 13 summarises key statistical differences in open space ownership across all metropolitan partnership boundaries compared to within the urban growth boundary.
- Table 14 provides an analysis of open space type and ownership measured by hectares (ha) and percentage (%) across Melbourne subregions, and as a proportion within the urban growth boundary. Open space definitions are available from the Victorian Planning Authority: https://vpa.vic.gov.au/wp-content/uploads/2017/06/Metropolitan-Open-Space-Strategy-Open-Space-Category-Definitions.pdf

Inside the urban growth boundary, significant increases in public land can be seen for parks and gardens, sports fields, organised recreation spaces, and recreation corridors. Declines are apparent in conservation reserves and natural and semi-natural open space. These occur on large areas of crown land outside the urban growth boundary, predominantly in the peri-urban municipalities of Whittlesea, Nillumbik, Yarra Ranges, Cardinia, Mornington Peninsula, and Wyndham.

Significant decreases in open space ownership inside the urban growth boundary occur for crown land (from 80.61% to 37.93%), and increases proportionally for local government (from 7.22% to 31.82%). Less significant increases in ownership are also indicated for state government, public authority, and private open space. Local government, managers of crown land, as well as public authorities and state government organisations, can therefore significantly influence the structure of the urban forest. It is also worth noting that 10.89% is private open space that may contribute to maintaining and enhancing biodiversity and the community's health and wellbeing.

Figure 20 provides a map of open space ownership by distribution across metropolitan Melbourne. Crown land, and land owned by local government, clearly makes up large proportions of the total open spaces within the urban growth boundary and broadly across the matrix of the metropolitan area.

Table 12 Open space by category and ownership for the total metropolitan area and as a proportion within the urban growth boundary (Source: Statistics derived from the Victorian Planning Authority's *Metropolitan Open Space Network Portal*)

	Total area of 32 Local Government Areas		Inside the urban growth boundary	
	Hectares	%	Hectares	%
Total Area of 32 Local Government Areas	**893,648**		**285,549**	
Total Open Space	**296,228**	**33%**	**53,744**	**19%**
Open Space Categories				
Parkland and garden	8,061	2.72%	6,329	11.78%
Conservation reserves	132,128	44.60%	6,247	11.62%
Natural and semi natural	120,942	40.83%	19,712	36.68%
Recreation corridor	1,162	0.39%	733	1.36%
Sports fields and organised	15,856	5.35%	11,052	20.56%
Civic square and promenade	29	0.01%	29	0.05%
Government schools	2,906	0.98%	2,788	5.19%
Non-Government schools	2,862	0.97%	2,500	4.65%
Cemeteries	1,159	0.39%	880	1.64%
Services and utilities reserves	8,689	2.93%	1,216	2.26%
Tertiary institutions	904	0.31%	828	1.54%
Transport reservations	1,518	0.51%	1,418	2.64%
Public housing reserves	11	0.00%	11	0.02%
Total Open Space	**296,229**	100.00%	**53,744**	100.00%

Table 13 Summary of key statistical differences in open space ownership across all metropolitan partnership boundaries as compared to within the urban growth boundary

Open Space Ownership	Total area of 32 Local Government Areas		Inside the Uurban Growth Boundary	
	Ha	%	Ha	%
Federal	22	0.01	3	0.01
Crown	238,796	80.61	20,382	37.93
State Government	14,146	4.78	3,508	6.53
Local Government	21,392	7.22	17,102	31.82
Public Authority	10,501	3.54	5,155	9.59
Private	8,981	3.03	5,854	10.89

Table 14 Open space type and ownership measured by hectares (ha) and percentage (%) across Melbourne sub-regions (Source: Statistics derived from the Victorian Planning Authority's *Metropolitan Open Space Network Portal*)

	Inner region		Inner South East		Western		Northern		Eastern		Southern		Total 32 LGA		Inside UGB	
	Totals	%	Totals	%	Totals	%	Total	%	Total	%	Total	%	**Grand Total**	**%**	**Sub-Total**	**%**
Total Area of Sub-Region (Ha)	**7,858**		**16,251**		**133,656**		**167,959**		**291,364**		**276,559**		**893,648**		**285,549**	
Total Open Space (Ha)	**2,357**		**2,568**		**33,050**		**36,340**		**172,576**		**49,338**		**296,228**		**53,744**	
Open Space		**30**		**16**		**25**		**22**		**59**		**18**		**33**		**19**
Crown road reserves (Estimate)															**37,121**	**13**
Open Space Categories																
Parkland and garden	628.39	26.67	357.39	13.92	1872.37	5.67	1567.98	4.31	1492.22	0.86	2142.08	4.34	8,060	2.72	6,329	11.78
Conservation reserves	0.00	0.00	12.02	0.47	13158.80	39.81	14151.66	38.94	83914.45	48.62	20891.33	42.34	132,128	44.60	6,247	11.62
Natural and semi natural	707.20	30.01	550.80	21.45	6756.87	20.44	15050.85	41.42	81002.37	46.94	16874.11	34.20	120,942	40.83	19,712	36.68
Recreation corridor	2.45	0.10	5.24	0.20	194.89	0.59	190.66	0.52	352.44	0.20	416.22	0.84	1,162	0.39	733	1.36
Sports fields and organised recreation	735.32	31.20	1123.97	43.77	2825.65	8.55	2381.62	6.55	3044.50	1.76	5745.29	11.64	15,856	5.35	11,052	20.56
Civic square and promenade	12.31	0.52	2.09	0.08	1.23	0.00	11.32	0.03	1.27	0.00	1.02	0.00	29	0.01	29	0.05
Government schools	55.91	2.37	156.33	6.09	557.05	1.69	634.47	1.75	717.22	0.42	785.46	1.59	2,906	0.98	2,788	5.19
Non Government schools	53.28	2.26	251.43	9.79	368.96	1.12	877.50	2.41	571.62	0.33	739.26	1.50	2,862	0.97	2,500	4.65
Cemeteries	51.17	2.17	45.80	1.78	225.67	0.68	361.07	0.99	88.44	0.05	387.09	0.78	1,159	0.39	880	1.64
Services and utilities reserves	2.20	0.09	8.30	0.32	6800.67	20.58	392.42	1.08	753.05	0.44	732.81	1.49	8,689	2.93	1,216	2.26
Tertiary institutions	74.56	3.16	23.02	0.90	150.73	0.46	364.62	1.00	167.67	0.10	123.34	0.25	904	0.31	828	1.54
Transport reservations	23.69	1.01	31.39	1.22	136.95	0.41	355.36	0.98	471.10	0.27	499.77	1.01	1,518	0.51	1,418	2.64
Public housing reserves	10.10	0.43	0.00	0.00	0.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11	0.00	11	0.02
Open Space Ownership																
Federal	0.00	0.00	0.00	0.00	1.67	0.01	1.34	0.00	0.00	0.00	18.91	0.01	22	0.01	3	0.01
Crown	1,840.92	78.12	662.68	25.81	13,935.34	42.16	24,468.27	67.33	162,850.45	94.36	35,038.67	20.30	238,796	80.61	20,382	37.93
State Government	92.94	3.94	159.33	6.21	11111.25	33.62	1125.05	3.10	853.39	0.49	804.17	0.47	14,146	4.78	3,508	6.53
Local Government	65.54	2.78	1009.28	39.31	4633.45	14.02	5347.18	14.71	4209.59	2.44	6127.33	3.55	21,392	7.22	17,102	31.82
Public Authority	39.15	1.66	47.35	1.84	1030.79	3.12	3590.22	9.88	2827.79	1.64	2965.98	1.72	10,501	3.54	5,155	9.59
Private	101.95	4.33	597.81	23.28	1631.16	4.94	1409.32	3.88	1441.56	0.84	3799.33	2.20	8,981	3.03	5,854	10.89
No Data	216.08	9.17	91.32	3.56	706.66	2.14	398.15	1.10	393.57	0.23	583.39	0.34	2,389	0.81	1,740	3.24
Total Open Space (Ha)	**2,356.58**	**100.00**	**2,567.77**	**100.00**	**3,3050.31**	**100.00**	**36,339.53**	**100.00**	**17,2576.34**	**100**	**49,337.79**	**29**	**296,228**	**100**	**53,744**	**100.00**

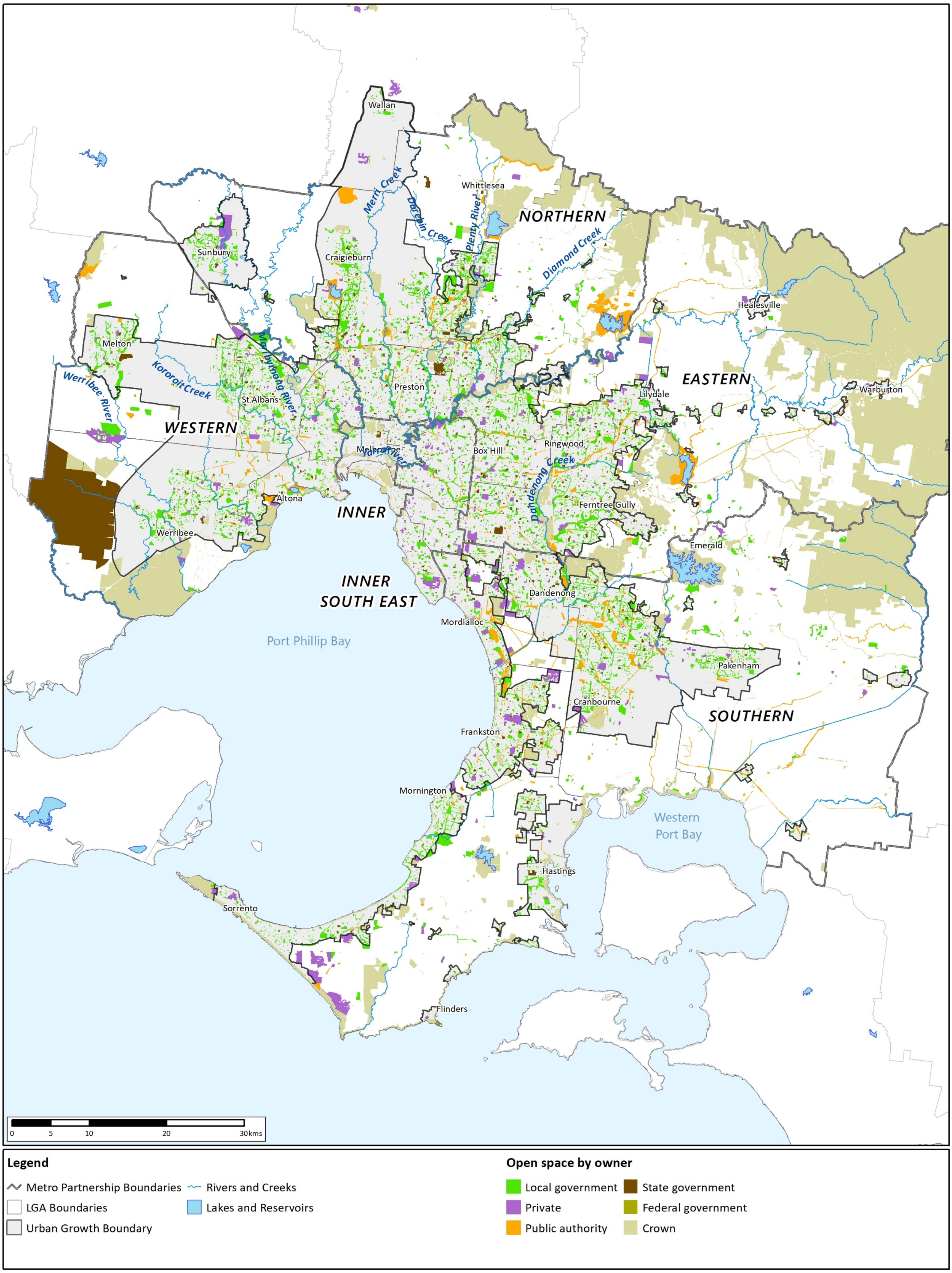


Figure 20 Distribution and ownership of open space across metropolitan Melbourne

6 Metropolitan Melbourne's urban forest

Figure 21 provides an overall illustration of metropolitan Melbourne's urban forest, overlayed on local government boundaries and the urban area of Melbourne. The existing urban area has been isolated in the analysis because it provides the existing vegetation cover in the urban area and discounts the statistical biases that occur when the large tracts of non-urban land (e.g. open rural land and state forests) are considered as part of the analysis. Please note that the existing urban area data layer for 2015 was used for this vegetation analysis. Following the completion of the analysis a 2017 urban area layer was identified. However, as the land area difference between the 2015 and 2017 data layers is approximately 2.2% it was considered that this difference was insufficient to warrant re-running the analysis. Any future analysis should use the most recent urban area data layer.

For the purposes of the analysis, 'understorey' is defined as vegetation with a height of less than 3 metres. 'Canopy' is defined as vegetation with a height above 3 metres.

The mapped area is limited by the data available at the time of processing. Most notably, this comprises the area between the Princes Highway and Princess Freeway at Pakenham, and the townships east of Pakenham within the Cardinia Shire Council. For this reason, the analysis should be considered in terms of 'mapped' vegetation.

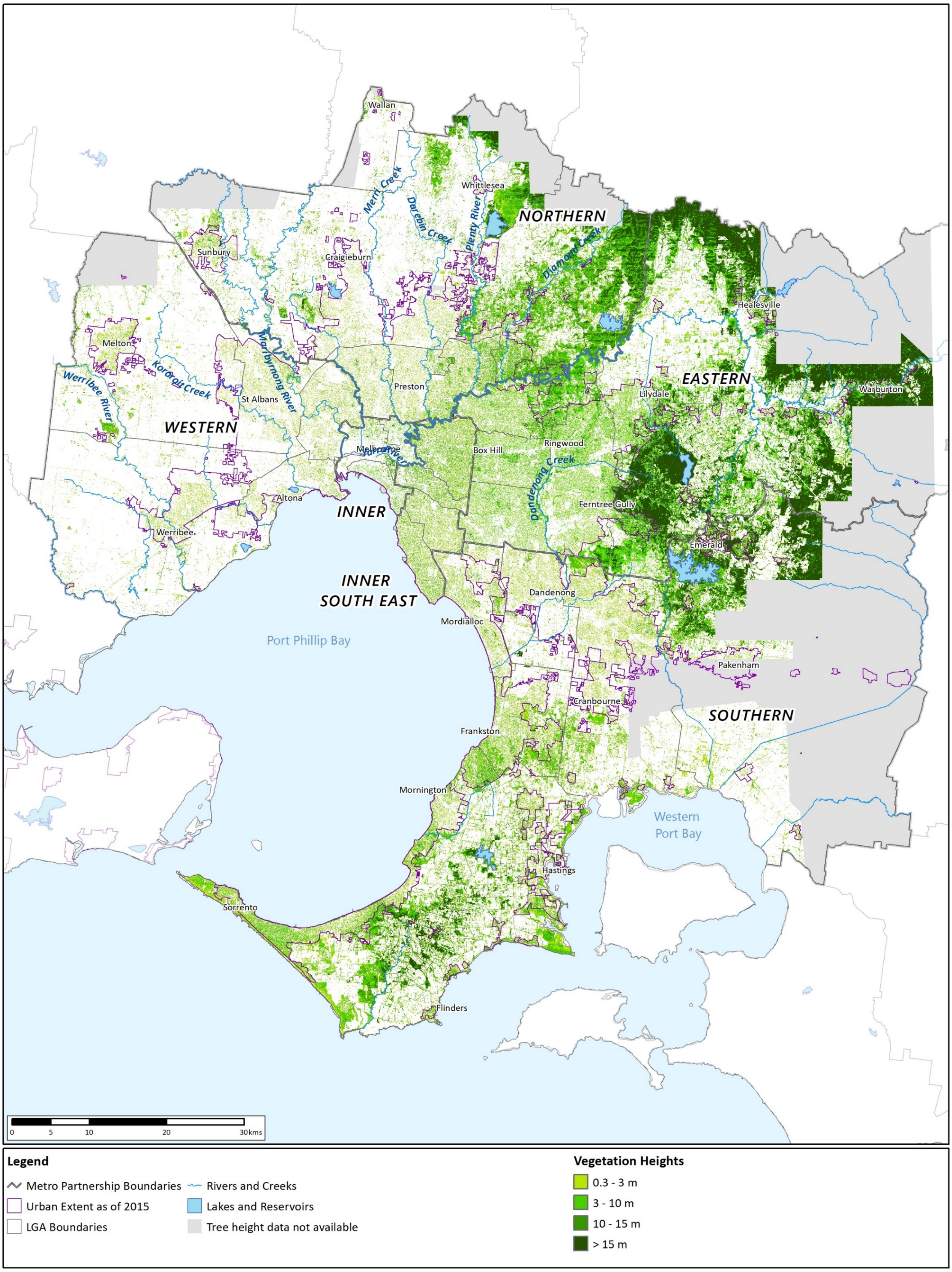


Figure 21 Metropolitan Melbourne's urban forest

Data Sources: 'Vicmap Admin', 'Road Network - Vicmap Transport', 'Watercourse Network 1:25,000 Vicmap Hydro', Copyright ©The State of Victoria, Department of Environment, Land, Water & Planning 2018; 'Urban Extent 2015' Copyright ©The State of Victoria, Department of Environment, Land, Water and Planning, 2016; LIDAR Projects: '2008-9 Greater Melbourne Urban LiDAR Project'; 'Victorian Coastal LIDAR Level 3 Classification (Port Phillip & Western Port)'; '2011 Melbourne & Surrounds Forest Structure LiDAR'; '2005-6 Outer South East Melbourne'; Copyright ©The State of Victoria, Department of Environment, Land, Water & Planning 2018. Satelite imagery: November 2016-March 2017, Copyright 2018 DigitalGlobe Incorporated; Mapping software: Courtesy of Trimble® eCognition® Essentials

6.1.1 Distribution of canopy cover across the metropolitan urban area

Table 15 provides a regional breakdown of the distribution of canopy cover across the existing urban area of metropolitan Melbourne. As a proportion of all vegetation, the urban area has a total canopy cover of 15.4%. In each region, percentage canopy cover is highest in the Eastern (25.2%) and Inner South East (21.7%) Regions, with the Southern (16.4%), Inner (12.5%), and Northern (12.1%) Regions providing lower canopy cover levels. Canopy cover is lowest in the Western Region (4.2%).

Table 15 Canopy cover within the existing urban area of Melbourne

Metropolitan Regions	Trees canopy 3 m to 15 m (%)
Eastern	25.2
Inner South East	21.7
Southern	16.4
Inner	12.5
Northern	12.1
Western	4.2
Total Metropolitan tree canopy	**15.4**

Table 16 provides a breakdown of the percentage cover of vegetation between zero metres and 15+ metres in height for each municipality by partnership region, and within the existing urban area of Melbourne. The total percentage of vegetation is lowest in the Inner Region (30.8%) and highest in the Eastern Region (57.2%). Nillumbik Shire Council (44.6%) has the highest percentage of canopy cover and the City of Wyndham the lowest (2.6%), other than the small portion of Mitchell Shire Council that is represented.

The City of Melton has the highest percentage of grass cover (32.7%), while the City of Stonnington has the lowest (5.5%).

In terms of shrub cover, Mornington Peninsula Shire has the highest percentage (20.8%), and City of Melbourne has the lowest (5.5%).

Understorey vegetation is highest in the Southern (38.6%), Eastern (32%), and Western Regions (30.3%), and lowest in the Inner Metropolitan Region (18.4%).

There is relatively little vegetation above 15 metres (large trees) across the urban area, with coverage generally ranging from 0.1–2.9%. Exceptions are the Yarra Ranges Council (7.7%), and the Cardinia Shire Council, with a relatively high proportion of large trees (14.1%).

It is also worth noting that small trees and shrubs, collectively, provide the majority of vegetation cover in all regions other than the Western Region, and in most municipalites.

Table 16 Percentage cover of vegetation between 0 m and 15+ m in height within the existing urban area of Melbourne by metropolitan region

Metropolitan Region	Local Government Area	0 - .30 m Grass	.30 – 3 m Shrub	3 m – 10 m Small tree	10 m – 15 m Medium tree	15 m+ Large tree	Understorey 0m – 3m	Canopy 3m - 15+m	Canopy plus shrub .30-3m + 3m-15+m	Total Vegetation
Eastern	KNOX	20.40%	18.20%	14.00%	2.60%	0.90%	38.60%	17.50%	35.70%	56.10%
	MANNINGHAM	12.70%	20.10%	20.80%	6.20%	2.80%	32.70%	29.80%	49.90%	62.50%
	MAROONDAH	11.20%	18.90%	22.60%	5.00%	1.40%	30.10%	29.00%	47.90%	59.20%
	MONASH	11.90%	18.20%	13.70%	1.80%	0.40%	30.10%	15.90%	34.10%	45.90%
	WHITEHORSE	8.50%	17.80%	19.60%	3.50%	0.80%	26.30%	23.90%	41.70%	50.20%
	YARRA RANGES	13.00%	18.40%	22.10%	8.10%	7.70%	31.30%	37.80%	56.20%	69.10%
Eastern Total		13.40%	18.60%	18.40%	4.40%	2.40%	32.00%	25.20%	43.80%	57.20%
Inner Metro	MELBOURNE	12.00%	5.50%	6.20%	2.40%	1.30%	17.50%	9.90%	15.40%	27.40%
	PORT PHILLIP	9.30%	9.40%	11.30%	2.10%	0.40%	18.70%	13.90%	23.30%	32.50%
	YARRA	10.00%	9.80%	11.40%	2.70%	1.70%	19.80%	15.80%	25.60%	35.70%
Inner Metro Total		10.80%	7.60%	8.80%	2.40%	1.20%	18.40%	12.50%	20.10%	30.80%
Inner South East	BAYSIDE	11.10%	18.60%	17.50%	2.00%	0.40%	29.70%	19.90%	38.50%	49.60%
	BOROONDARA	8.20%	18.30%	21.70%	3.90%	1.10%	26.50%	26.80%	45.10%	53.20%
	GLEN EIRA	8.50%	18.40%	13.00%	1.10%	0.20%	26.80%	14.30%	32.70%	41.10%
	STONNINGTON	5.50%	13.80%	19.40%	3.30%	0.70%	19.30%	23.40%	37.20%	42.70%
Inner South East Total		8.50%	17.70%	18.30%	2.70%	0.70%	26.10%	21.70%	39.40%	47.80%
Northern	BANYULE	12.60%	17.20%	18.70%	3.90%	1.40%	29.80%	24.00%	41.20%	53.80%
	DAREBIN	13.40%	14.50%	8.10%	1.10%	0.40%	27.90%	9.50%	24.00%	37.40%
	HUME	18.20%	9.10%	3.90%	0.60%	0.10%	27.20%	4.60%	13.70%	31.90%
	MITCHELL	18.10%	0.10%	0.10%	0.00%	0.00%	18.20%	0.10%	0.20%	18.30%
	MORELAND	10.90%	12.90%	6.50%	0.60%	0.20%	23.80%	7.30%	20.20%	31.10%
	NILLUMBIK	8.00%	14.50%	31.10%	10.60%	2.90%	22.40%	44.60%	59.10%	67.10%
	WHITTLESEA	17.00%	9.40%	3.30%	0.50%	0.10%	26.30%	3.90%	13.30%	30.20%
Northern Total		14.60%	12.10%	9.40%	2.00%	0.60%	26.70%	12.10%	24.20%	38.70%
Southern	CARDINIA	21.40%	13.50%	12.80%	7.10%	14.10%	34.90%	34.10%	47.60%	69.00%
	CASEY	29.80%	18.50%	6.70%	0.80%	0.20%	48.20%	7.70%	26.20%	55.90%
	FRANKSTON	16.10%	20.20%	16.90%	2.40%	0.50%	36.30%	19.80%	40.00%	56.10%
	GREATER DANDENONG	19.90%	12.60%	4.80%	0.70%	0.10%	32.50%	5.70%	18.30%	38.10%
	KINGSTON	16.00%	15.30%	7.60%	0.90%	0.50%	31.30%	9.00%	24.30%	40.30%
	MORNINGTON PENINSULA	17.70%	20.80%	23.10%	3.30%	0.90%	38.50%	27.30%	48.10%	65.80%
Southern Total		20.80%	17.80%	13.00%	2.10%	1.20%	38.60%	16.40%	34.20%	55.00%
Western	BRIMBANK	16.50%	10.50%	3.40%	0.40%	0.40%	27.10%	4.20%	14.70%	31.30%
	HOBSONS BAY	17.20%	10.60%	3.80%	0.30%	0.30%	27.80%	4.40%	15.00%	32.10%
	MARIBYRNONG	12.50%	11.00%	5.00%	0.50%	0.40%	23.50%	5.90%	16.90%	29.40%
	MELTON	32.70%	12.50%	2.80%	0.20%	0.00%	45.20%	3.10%	15.60%	48.30%
	MOONEE VALLEY	11.50%	13.50%	7.10%	0.60%	0.20%	25.10%	7.90%	21.40%	33.00%
	WYNDHAM	21.40%	9.00%	2.30%	0.20%	0.10%	30.40%	2.60%	11.60%	33.10%
Western Total		19.50%	10.80%	3.60%	0.40%	0.20%	30.30%	4.20%	15.00%	34.50%
Grand Total		**16.30%**	**15.10%**	**11.90%**	**2.30%**	**1.10%**	**31.40%**	**15.40%**	**30.50%**	**46.80%**

Figure 22 provides the percentage of three simplified vegetation classes, trees (> 3 m in height), shrubs (0.3-3 metres) and grasses (< 0.3 m) by total urban area and partnership region. Across the urban area, the overall proportional coverage is similar, but between and within regions the proportions vary significantly. The figure also indicates the high proportion of grass in the Western and Southern Regions, and he high proportion of trees in the Eastern and Inner South East Regions.

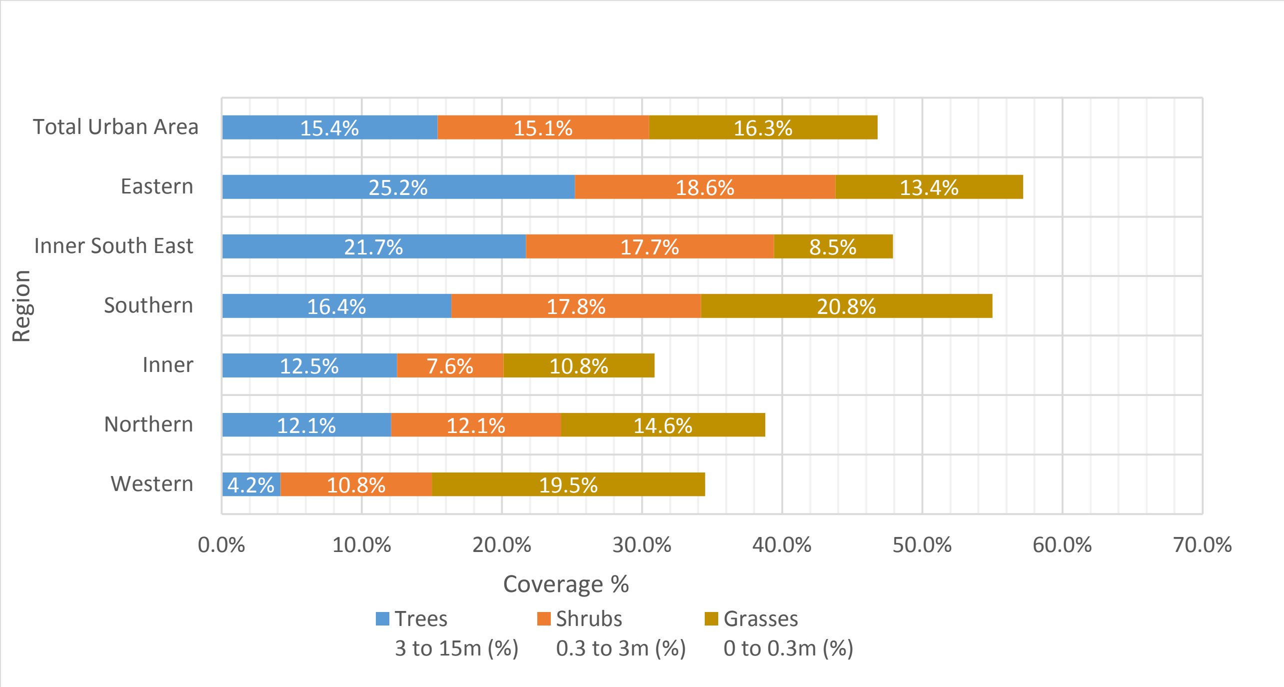


Figure 22 Percentage cover of simplified vegetation types (grass, shrubs, trees) within the urban area by metropolitan region

Figures 23 to 28 provide regional maps of the vegetation height and distribution across Melbourne. Please note that while grass cover (the lowest vegetation height class – 0 to 0.3 metres) is an essential element of the vegetation across Melbourne, the maps do not display grass cover as it provides a distorting effect.

Figure 23 Western Region

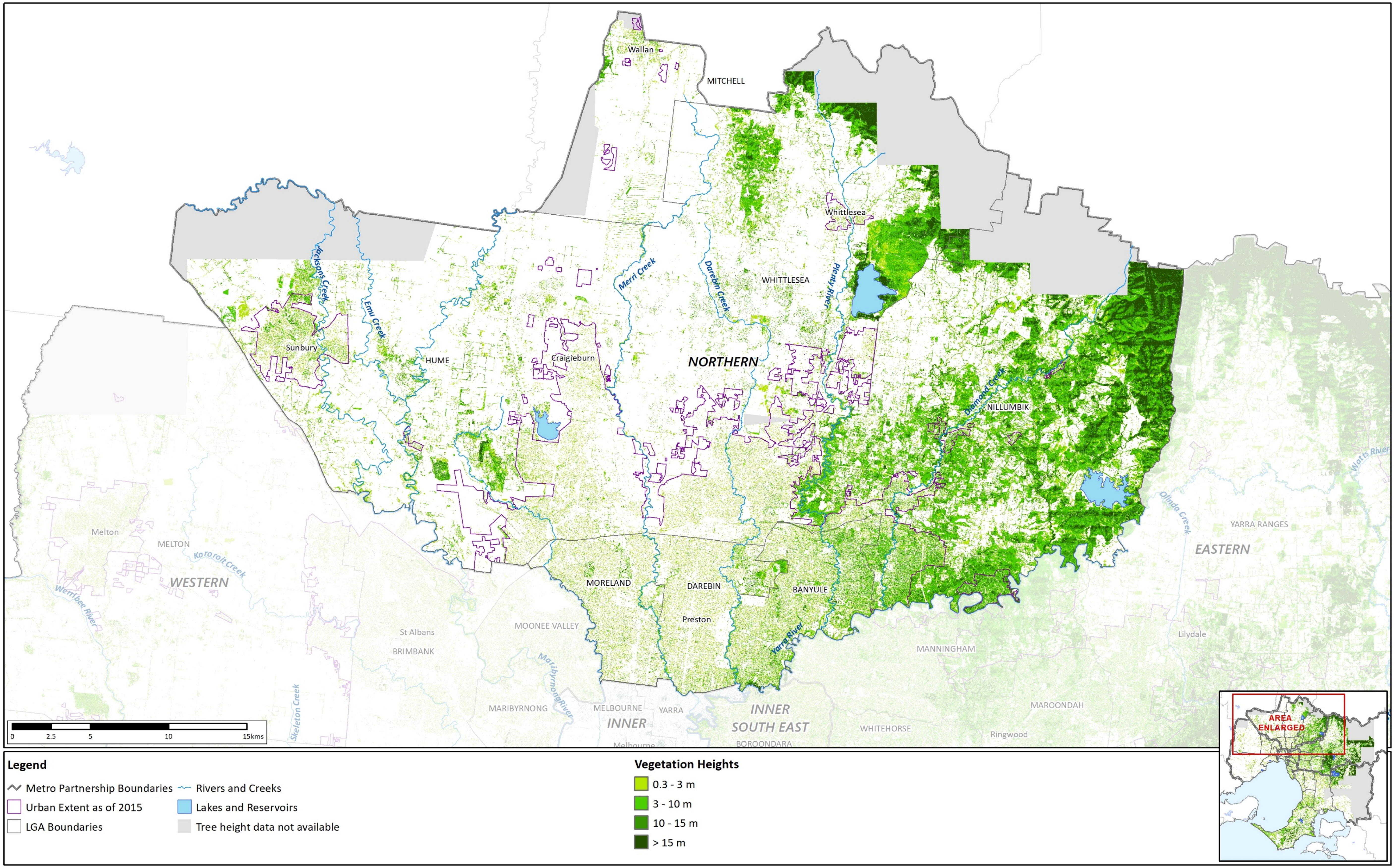


Figure 24 Northern Region Region

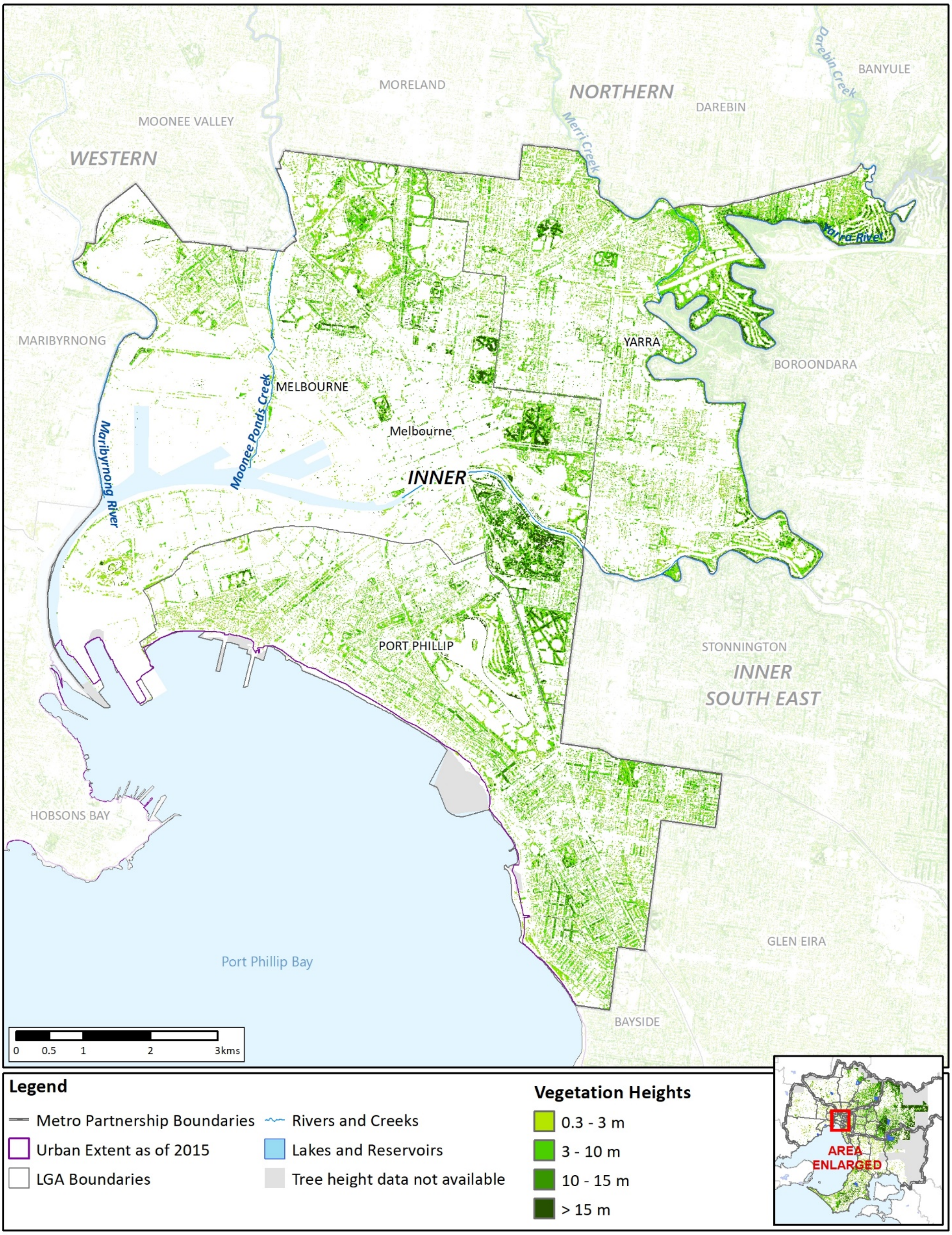


Figure 25 Inner Region

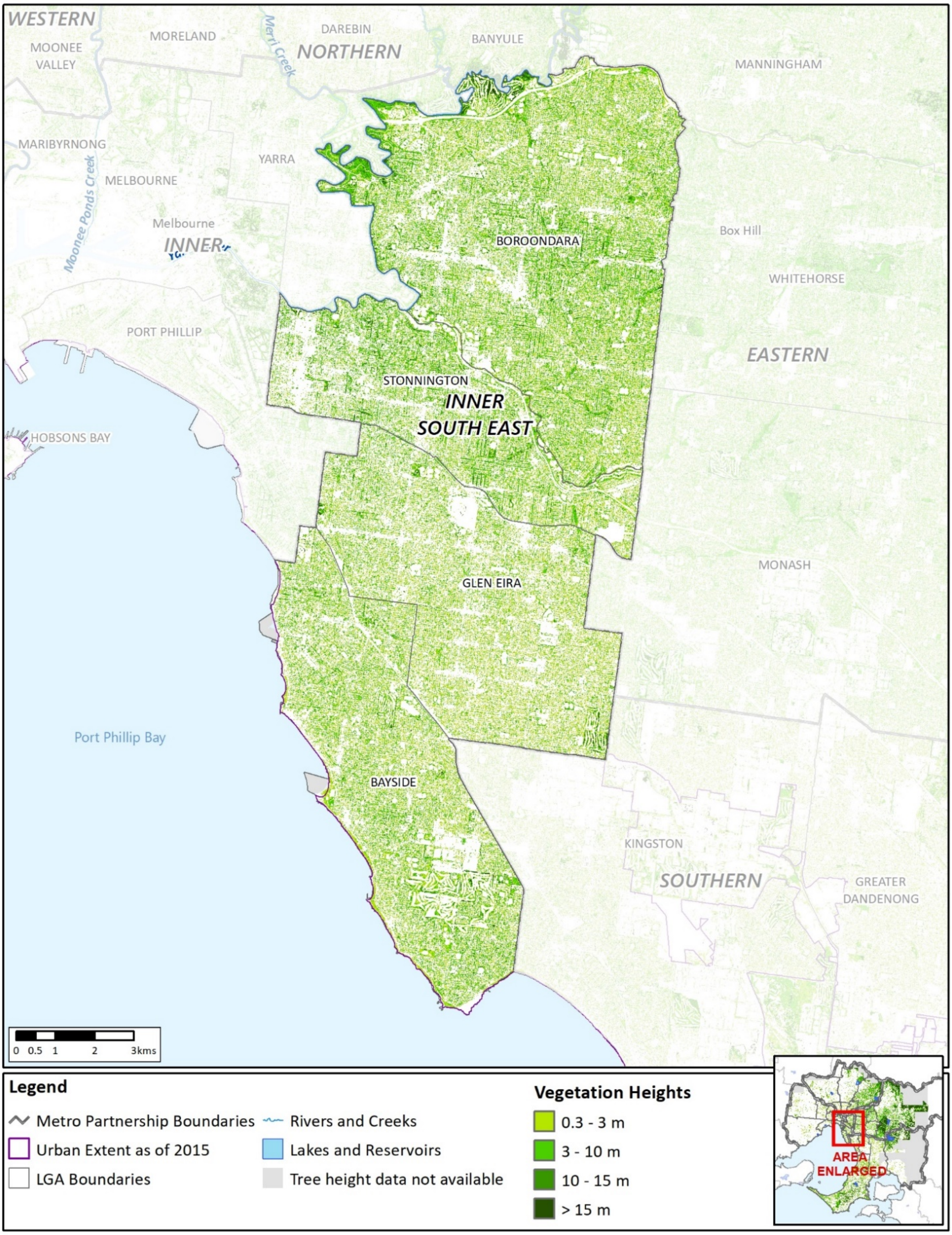


Figure 26 Inner South East Region

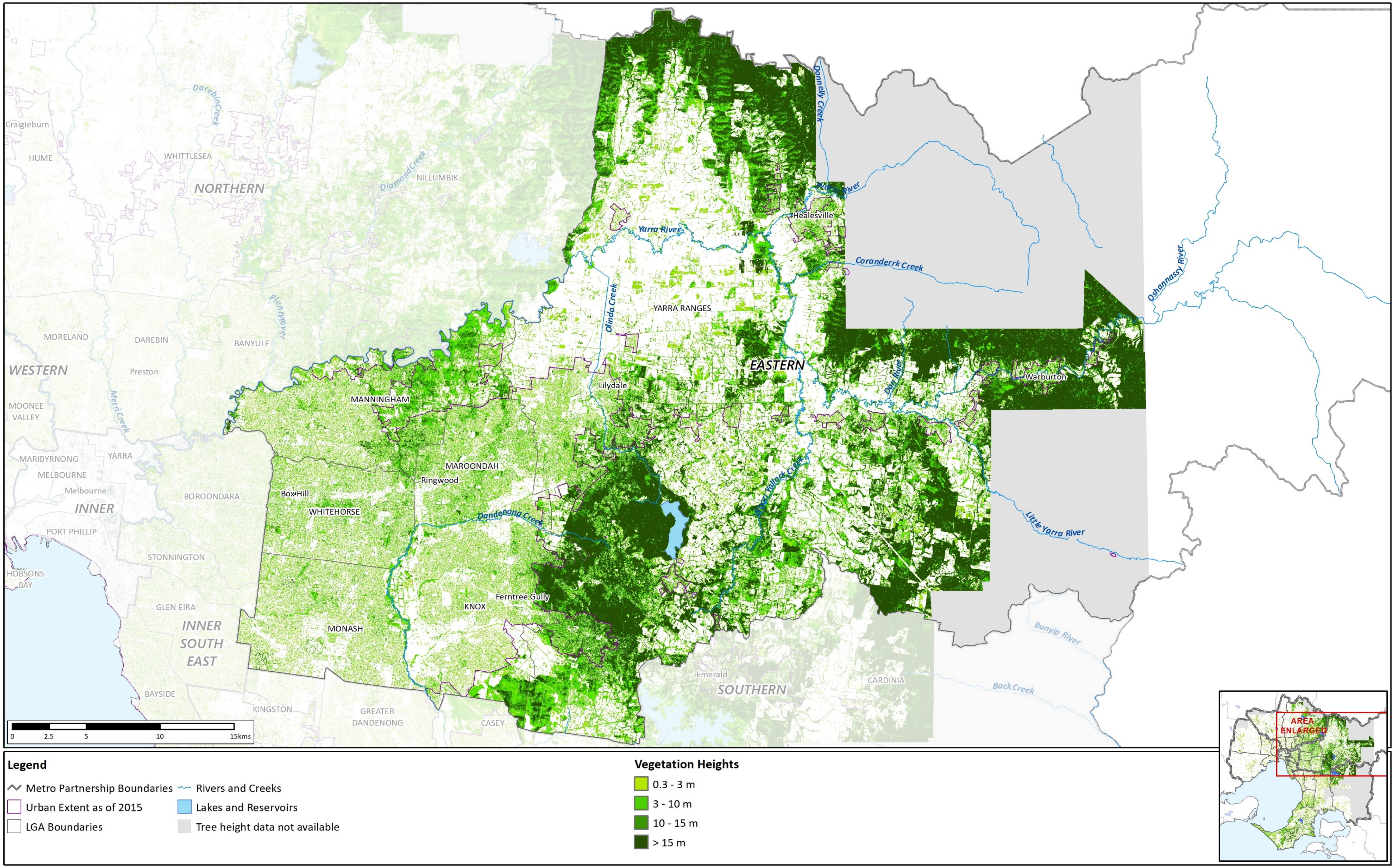


Figure 27 Eastern Region

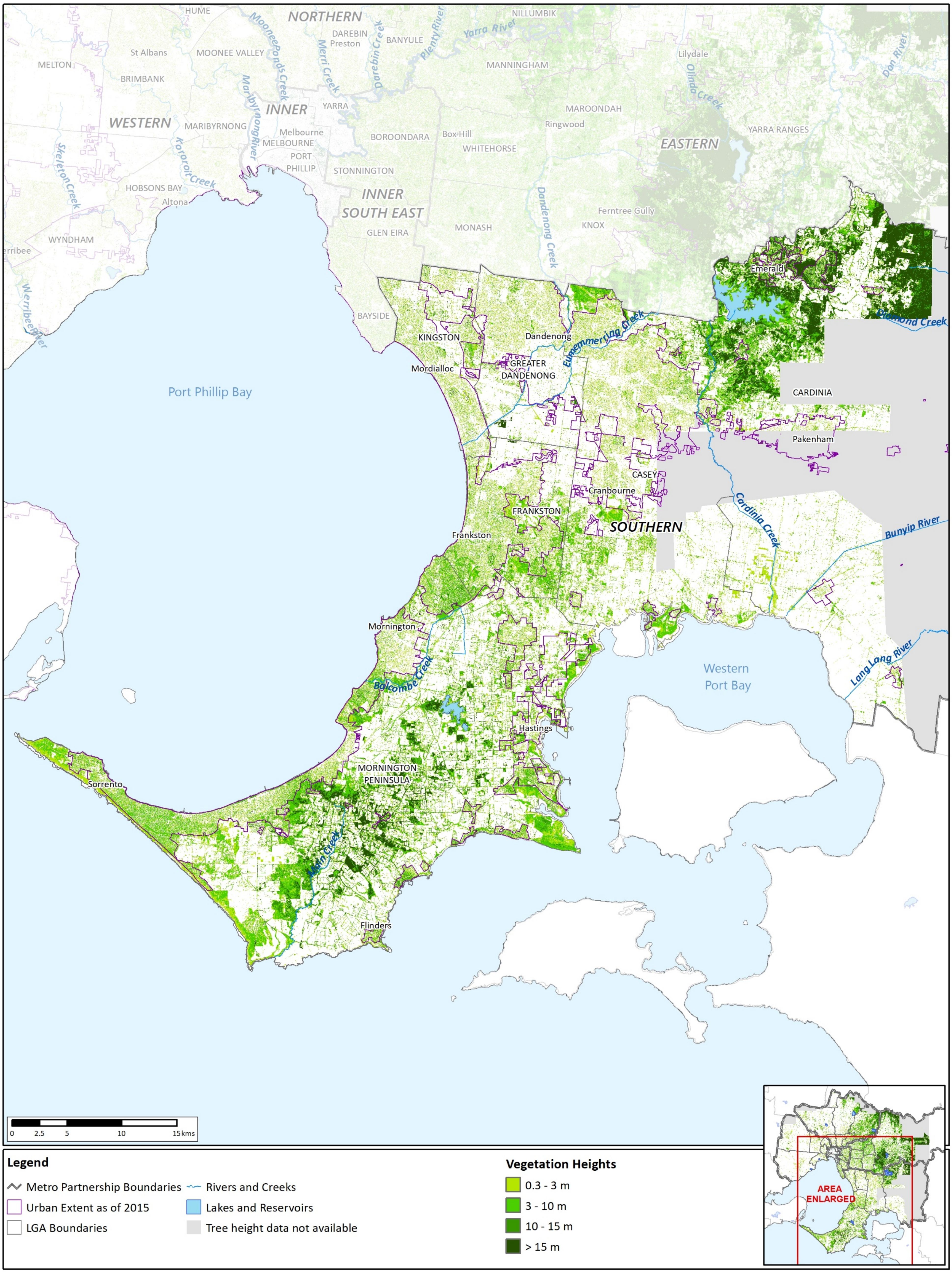


Figure 28 **Southern Region**

6.1.2 Vegetation analysis by land use type

Modified Victorian planning zone groups were used to analyse vegetation percentage (canopy cover) by land use type. For the urban area of Melbourne, these are shown in Tables 17 - 22 and represented graphically in Figures 29-35 When focussing only on canopy cover, it is apparent that by far the greatest contribution is made by residential zones, followed at some distance by public land and road reserves.

The following tables and graphs provide a region-by-region analysis of the above breakdown by land use type. Land zoned for residential purposes provides the highest level of canopy cover in all regions except the Inner Region. Public land and road reserves commonly provide the next largest proportional representation of cover. In the Inner Region, canopy cover on public land is 44% and on roads reserves 25%.

Please note that land use type (e.g. Commonwealth or Rural) with a canopy contribution of zero is not illustrated in the associated pie chart.

Table 17 Percentage canopy cover by land use type across the urban area metropolitan Melbourne

Planning zone group	% total canopy cover
Residential	58%
Public	18%
Road reserves	16%
Special Purpose	4%
Rural	2%
Industrial	1%
Commercial	1%
Commonwealth	0.3%*

Note: Commonwealth land included to indicate that this land use type is considered but effective canopy is 0%. Rounding of figures was consistently applied.

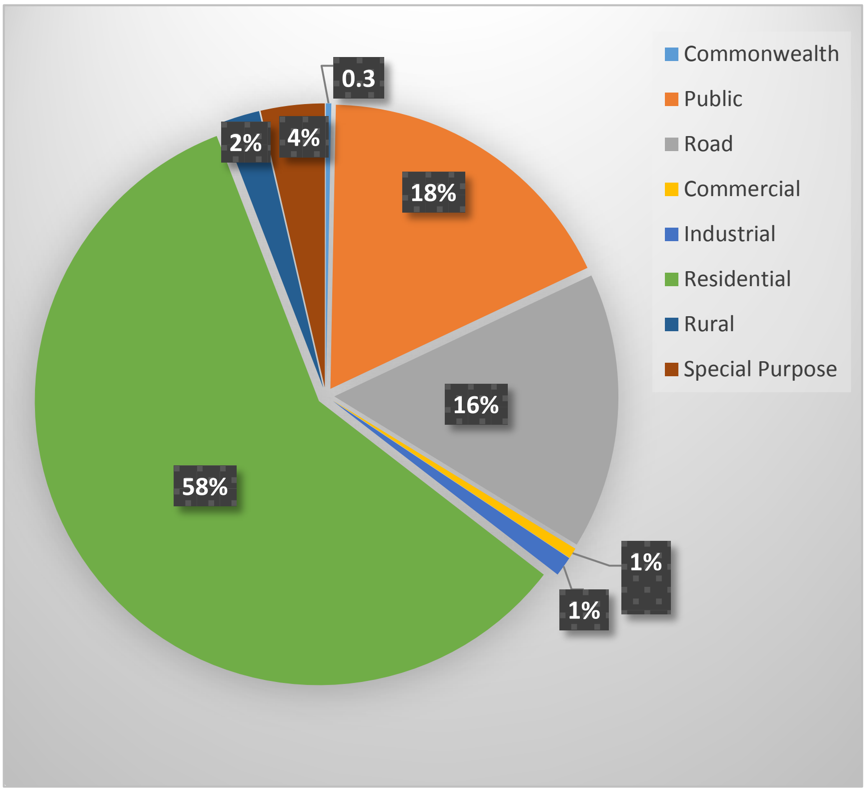


Figure 29 Percentage canopy cover by land use type across the urban area of metropolitan Melbourne

Table 18 Percentage canopy cover by land use type across the urban area of the Eastern Region

Planning zone group	% total canopy cover
Residential	61%
Public	17%
Road	14%
Rural	4%
Special Purpose	2%
Commercial	1%
Industrial	1%
Commonwealth	0%

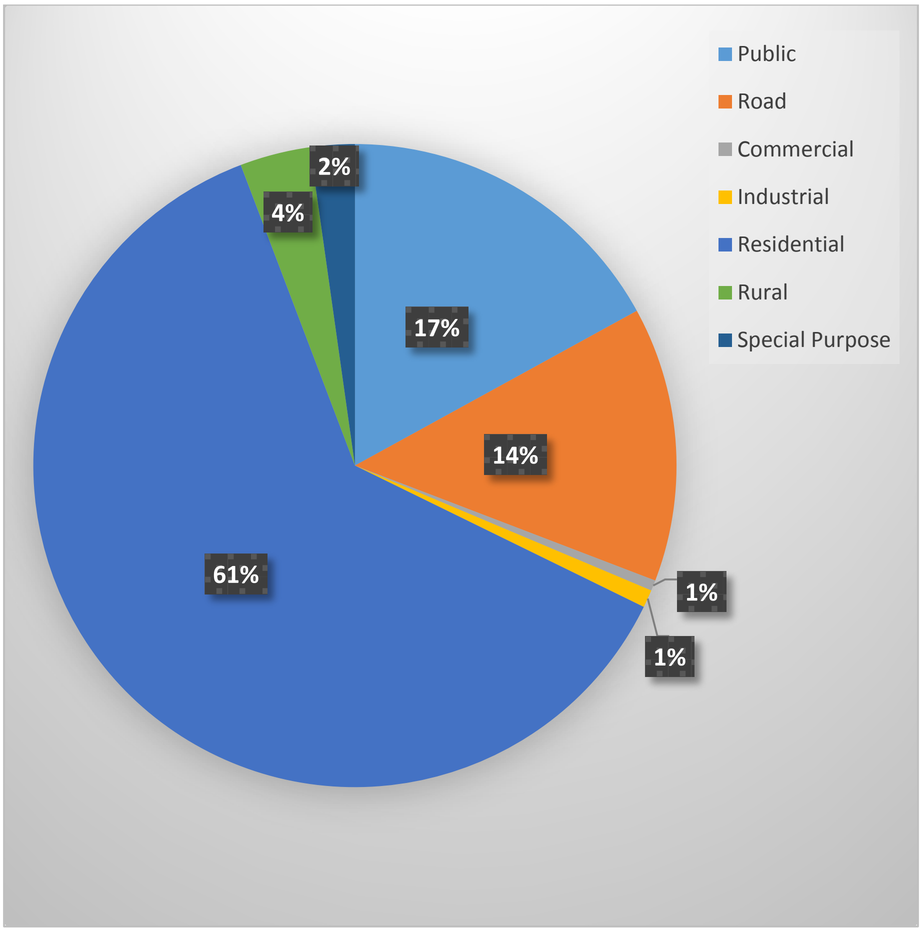


Figure 30 Percentage canopy cover by land use type across the urban area of the Eastern Region

Table 19 Percentage canopy cover by land use type across the urban area of the Inner Region

Planning zone group	% total canopy cover
Public	44%
Road	25%
Residential	23%
Special Purpose	5%
Commercial	2%
Industrial	1%
Rural	0%
Commonwealth	0%

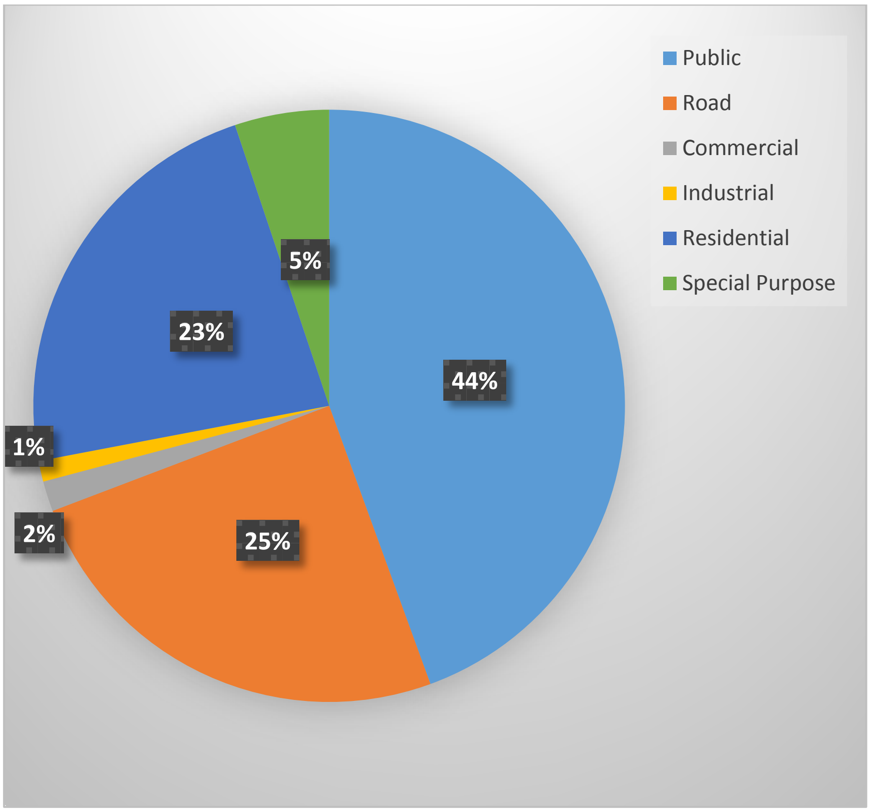


Figure 31 Percentage canopy cover by land use type across the urban area of the Inner Region

Table 20 Percentage canopy cover by land use type across the urban area of the Inner South East Region

Planning zone group	% total canopy cover
Residential	60%
Road	22%
Public	15%
Special Purpose	2%
Commercial	1%
Industrial	0%
Rural	0%
Commonwealth	0%

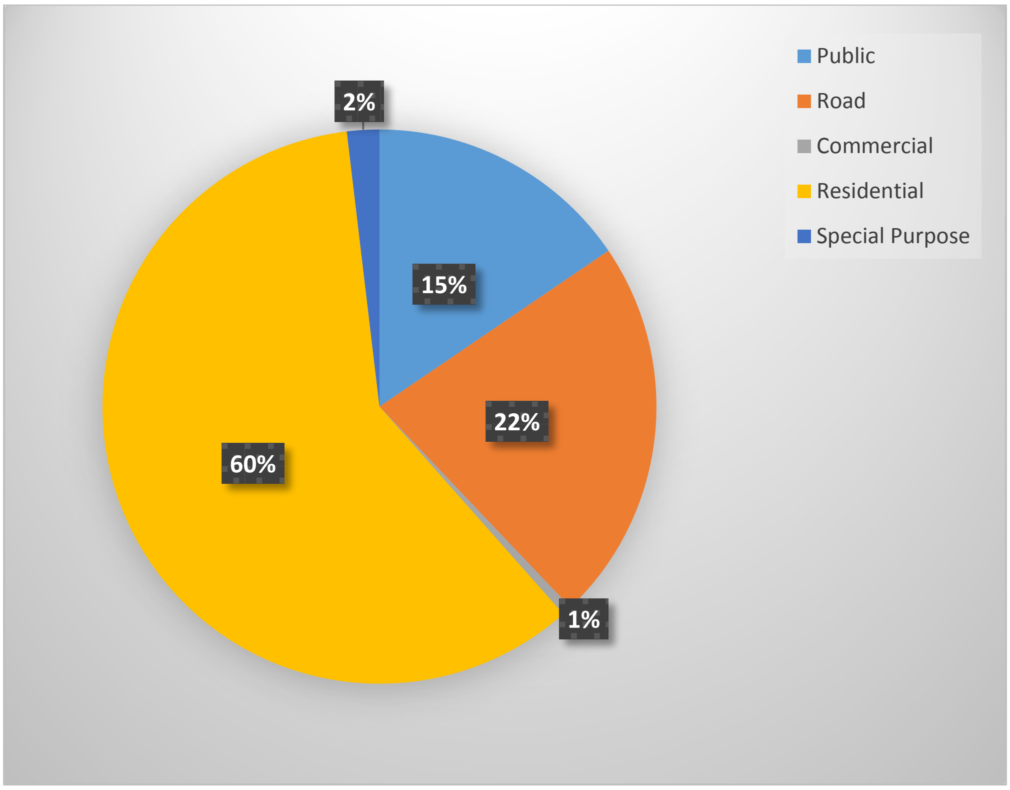


Figure 32 Percentage canopy cover by land use type across the urban area of the Inner South East Region

Table 21 Percentage canopy cover by land use type across the urban area of the Southern Region

Planning zone group	% total canopy cover
Residential	62%
Road	15%
Public	13%
Special Purpose	6%
Rural	2%
Commercial	1%
Industrial	1%
Commonwealth	0%

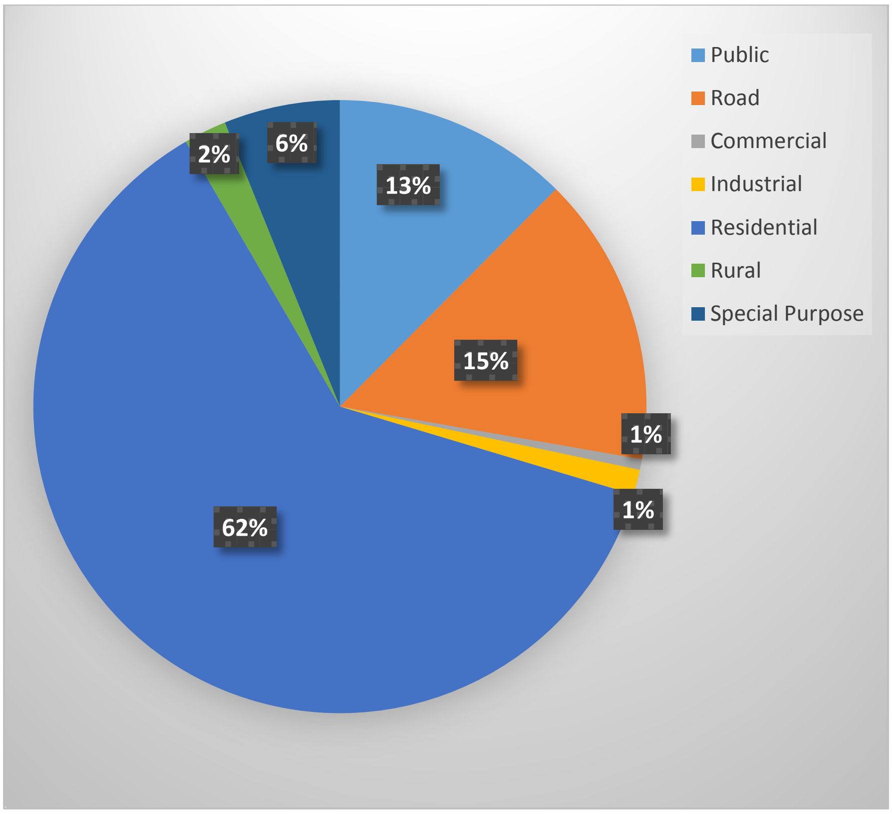


Figure 33 Percentage canopy cover by land use type across the urban area of the Southern Region

Table 22 Percentage canopy cover by land use type across the urban area of the Northern Region

Planning zone group	% total canopy cover
Residential	56%
Public	22%
Road	14%
Special Purpose	3%
Rural	2%
Commercial	1%
Industrial	1%
Commonwealth	1%

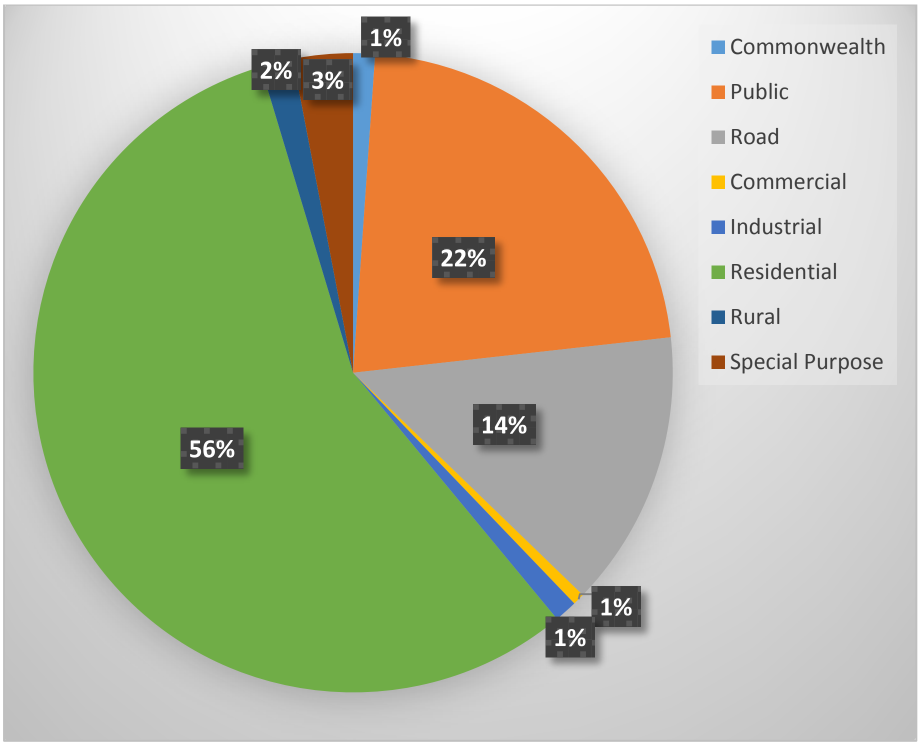


Figure 34 Percentage canopy cover by land use type across the urban area of the Northern Region

Table 23 **Percentage canopy cover by land use type across the urban area of the Western Region**

Planning zone group	% total canopy cover
Residential	43%
Public	28%
Road	18%
Industrial	4%
Special Purpose	4%
Commonwealth	2%
Commercial	1%
Rural	0%

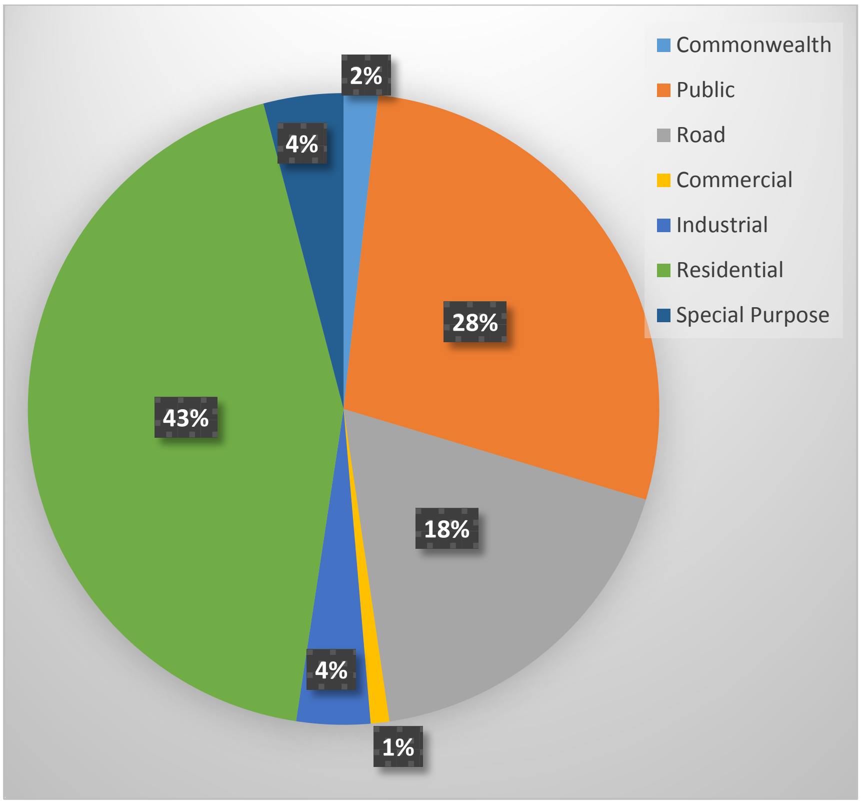


Figure 35 **Percentage canopy cover by land use type across the urban area of the Western Region**

6.2 Methods and accuracy

6.2.1 Source data

The source data utilised for this project were Victorian Government LiDAR datasets (2005-2006, 2008–2009, 2011-12 and 2012–2013), Digital Terrain Model (DTM) and Digital Surface Model (DSM), both with 1 m resolutions, as well as a 2 m resolution Digital Globe 8-Band satellite imagery dataset (2016-2017). None of supplied datasets included accuracy metadata. The spatial accuracy was visually reviewed by comparing the three datasets against each other, and overlaid over a combination of ESRI's basedata imagery and Google Earth (when older aerials were required).

Overall the quality was good, and no considerable deviations were found. The following comments were made about the source data.

Lidar- DSM: The DSM dataset was of good quality, yet 10 artefacts were found, which had to be accepted and were deemed not large enough to warrant further actions

Lidar- DTM: The DTM was provided in tiled format, which was mosaiced using ArcGIS prior to analysis.

Satellite Imagery: The Digital Globe satellite imagery was reviewed against existing online imagery and was estimated to be about 1-2 pixels within the comparison imagery. A small strip of data is missing in the North East of the dataset. The satellite imagery was particularly impacted by the dates and times of the imagery being captured. In some circumstances there was as much as two years between the adjoining aerial data sets. This was evident not only in the visual Red Green Blue components of the raster, but also in the Normalised Difference Vegetation Index (NDVI values). These can fluctuate considerably between scenes if recorded at different times of the year when moisture and vegetation is abundant, or not, as it would be after a dry period.

Overall, the source data provided was well suited and of good quality (Morphum Environmental, 2018). The data was processed using Trimble eCogntion software. The process involved setting up a workflow that uses various GIS tools and filters to create the final deliverables.

6.2.2 Accuracy

The Overall Accuracy of the Metro Melbourne Urban Vegetation Height Dataset is 82.0% (Table 24), with Producer's Accuracy ranging from 74.3% (Height Class 4) to 90.1% (Height Class 1), and User's Accuracy ranging from 80.0% (Height Class 5) to 85.0% (Height Class 4). When the height classes are condensed down to belonging to Understory Vegetation (< 3.0 m) or Tree Canopy (> 3.0 m), the Overall Accuracy increases to 94.5%, with Producer's Accuracy and User's Accuracy for individual classes above 90% (Table 25).

Table 24 Accuracy by Height Class

	DSM Height Value – equivalent class						**Producer's Accuracy**
	1	**2**	**3**	**4**	**5**	**Total**	
1	**885**	96	1	0	0	982	90.1%
2	196	**1113**	90	2	0	1401	79.4%
3	20	114	**835**	34	5	1008	82.8%
4	2	0	110	**436**	39	587	74.3%
5	2	0	4	41	**176**	223	78.9%
Total	1105	1323	1040	513	220	4201	
User's Accuracy	80.1%	84.1%	80.3%	85.0%	80.0%		**82.0%**

Table 25 Accuracy by Condensed Height Class (Understory < 3.0 m, Tree Canopy > 3.0 m)

	DSM Height Value – equivalent class			Producer's Accuracy
	1,2	**3,4,5**	**Total**	
< 3.0 m	**2290**	93	982	96.1%
> 3.0 m	138	**1680**	1818	92.4%
Total	2428	1773	4201	
User's Accuracy	94.3%	94.8%		**94.5%**

6.2.3 Vegetation modelling

The vegetation mapping was modelled against a range of social and environmental drivers that best explain the patterns of vegetation cover across Melbourne. The aim of this modelling was to understand how vegetation cover (canopy, understory, and total vegetation) relates to six commonly identified drivers of tree and vegetation cover.

Analysis method

A 1km x 1km regular grid was created across the extent of the *Living Melbourne* urban forest structure dataset. Any 1km x 1km grid cells that fell on the boundary of the Melbourne Urban Forest Structure dataset extent were excluded, so that only grid cells with full coverage were considered. For each grid cell, predictor and response variable were calculated.

The predictor variables included:

- Mean annual rainfall – indicates moisture availability
- Bioregion - indicates soil and local climate conditions
- Density of people - indicates urban intensity
- SEIFA Index of Relative Social Disadvantage - indicates access to employment, education, and other services
- Percent of dwellings that are rented - indicates ownership and resident investment
- Percentage cover of surface water - indicates the terrestrial area available for vegetation

The response variables included:

- Percentage cover vegetation canopy - measures the extent of tree canopy > 3 metres height
- Percentage cover vegetation understory - measures the extent of vegetation < 3 metres height
- Percentage cover total vegetation - measures the extent of total vegetation cover

Boosted regression trees were also used. Boosted regression trees are a machine learning technique that can be thought of like a regression equation. The actual model is fitted using two algorithms (‘regression trees’ and ‘boosting’), and the outputs quantify how much of the variation in the response variable can be explained by each of the predictor variables. The most influential drivers will explain the largest percentage of variation.

Results

The results of the modelling found that average annual rainfall was a strong driver of percentage cover of vegetation for all three (canopy, understorey and total vegetation) classes examined. The modelled trends between average annual rainfall and the percentage cover of vegetation classes reflect the well-documented trends of highest tree canopy cover in the eastern and northern parts of the city.

However, understorey vegetation cover was highest in the lower rainfall areas, indicating that much of the vegetation in these drier areas is in the lower height bands. It may also reflect the fact that the metropolitan urban forest height dataset shows the height of the tallest vegetation. There may be understorey vegetation below the taller tree canopies, but it is not represented in the dataset.

The mean density of people per hectare (people/ha) explained approximately 10% of the vegetation cover patterns for all three classes examined here. In all examples, the amount of vegetation cover changed rapidly at low values of people/ha, before levelling off at values above approximately 50 people/ha. At low values of people/ha, total vegetation and understorey vegetation over decreased, reflecting the difficulty of maintaining ground level and low vegetation in areas with higher densities of people. At low values of people/ha, tree canopy cover increased, possibly reflecting the large areas in the western part of the study area with low people/ha and high understorey vegetation cover.

7 Heat in the landscape analysis

Landscape and demographic characteristics of urban heat island hot spots and cool spots were analysed across the urban area of Melbourne (Figure 36). Regional maps are provided at the end of this chapter (Figures 37-42). This analysis is confined to the 2015 urban area to minimise the the statistical biases of including the large areas of either forest landscape or open farmland. In addition, following the completion of the analysis, a 2017 urban area data layer was identified. However, as the land area difference between the 2015 and 2017 data layers is approximately 2.2% it was considered that this difference was insufficient to warrant re-running the analysis. Any future analysis should seek to use the most recent urban area data layer. As a result, where the term 'Melbourne' is used, it refers to the urban area of Melbourne as described above.

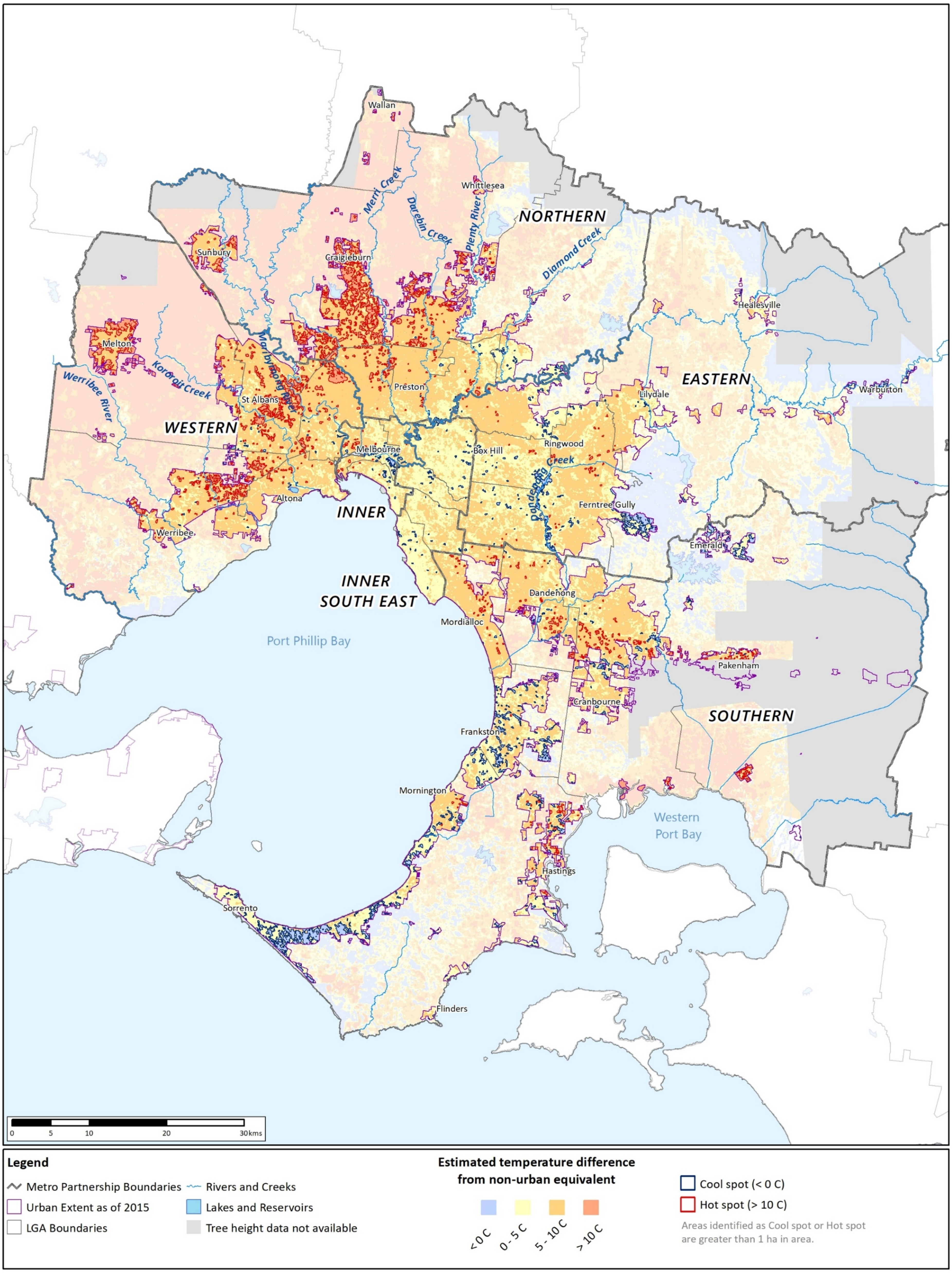


Figure 36 Map of urban heat island across metropolitan Melbourne, with hot spots (> 10°C warmer than non-urban condition) or urban heat island cool spots (< 0°C cooler than non-urban conditions) features shown in bright red and dark blue respectively. To view these maps by Region see Figures 40-45.

7.1 Aim of the analysis

1. To understand the geographic distribution of areas within the Melbourne urban area that are either urban heat island hot spots (> 10°C warmer than non-urban condition) or urban heat island cool spots (< 0°C cooler than non-urban conditions), based on the urban heat island data from Caccetta et al. (Caccetta, et al., 2017)
2. To identify differences in the landscape and demographic characteristics of areas in the landscape that are either urban heat island hot spots (> 10°C warmer than non-urban condition) or urban heat island cool spots (< 0°C cooler than non-urban conditions).

7.2 Background

The built structures and surfaces in urban areas absorb and store higher levels of solar radiation than surfaces covered by plants, creating locations where the temperature is higher than in the surrounding non-urban areas. This phenomenon has been described as an *urban heat island* and can be observed most strongly over-night as the thermal mass of concrete another common building materials release heat more slowly than natural materials or vegetation (Coutts, et al., 2010). The magnitude of the urban heat island can also vary at finer scales across an urban area, depending on the amount of plant cover and the thermal mass of materials in the landscape.

This report uses a publicly available spatial dataset of urban heat island temperatures across Melbourne, which are based on Land Surface Temperatures (absolute temperature values) captured on multiple days between October 2015 -April 2016 at approximately 10 am AEST by Landsat 8 (Amati, et al., 2017). The land surface temperature data for forested areas was used to create a model of non-urban temperatures that approximated how land surface temperatures varied with Latitude, Elevation and distance from the coast. The urban heat island dataset is the residual temperature difference between the actual mean land surface temperature value, and the modelled value of non-urban land surface temperature for that location. **It therefore provides an estimation of how different the temperature is in a location, relative to the temperature than would be there in the absence of urban development**.

Note: As the non-urban baseline was modelled on forested areas, there may be a tendency to over-estimate urban heat island in grassy ecosystems (e.g., native grasslands and pasture in the north and west of the study area). However, due to the consistent nature of the bias and the known prevalence of urban heat island issues in these areas, this is unlikely to affect the trends described in this report.

7.3 Key Findings

- Close to half of the urban area has urban heat island values of > 5°C., indicating substantial challenges in reducing the magnitude and extent of urban heat island in Melbourne.
- Over 80% of the urban area within the of the Northern and Western Regions have urban heat island values > 5°C. These Regions also had the highest number of hot spots (400+ each) with the largest average area (~12 ha), suggesting that these are potential priority areas for action and investment, building upon existing programs such as "Greening the West".
- The largest and greatest abundance of cool spots are in the Eastern and Southern Regions. Preserving these larger consolidated cool spots should be a priority.
- There were relatively few cool spots in the Inner and Inner South East Regions, and the Inner South East didn't have any hot spot features. These Regions were characterized by a large extent of urban heat island values of 0-5°C, which may provide potential insights into how to maintain lower urban heat island values across the Melbourne area. Maintaining these

lower urban heat island values into the future is likely to be a key consideration and potential aspirational benchmark for these regions.

- Cool spots supported a much higher ‘Percent Cover of Tree Canopy’, highlighting the importance of increasing tree canopy as a critical action for reducing urban heat island across Melbourne. This is particularly important in Melbourne where the capacity for Low Vegetation to deliver a cooling effect is strongly influenced by the moisture content of the soil and vegetation, and thus dependent upon supplemental watering programs.
- Within Regions, hot spots tended to be located in areas with relatively lower Average Annual Rainfall levels. Actions that prioritise water availability in these lower rainfall areas could help to counter these trends.
- Residential Planning Zones were strongly represented within both hot spots and cool spots, particularly in the Northern, Western and Southern Regions. Other Planning Zone groups that were strongly represented in hot spots and cool spots across Melbourne were: Public Land (e.g. Parks and Recreation zones), Roads, Industrial and Special Purpose Zones. Their strong representation reflects both the prevalence of these Planning Zone Groups within Melbourne, but also highlights the important role that the design has on the local urban heat island. Examining characteristics of these areas at a finer scale could offer constructive insights into how to create cooler neighbourhoods in a manner that is compatible with the associated land use.
- The demographic characteristics of hot spots and cool spots support previously identified links between urban heat island exposure risks and social vulnerability factors. Hot spots were generally characterized by lower Average Weekly Household income, lower values of the SEIFA Index of Relative Social Disadvantage (IRSD), higher Percent of Dwellings that were Rentals, and a higher Density of People/ha. These results highlight the opportunities for delivering improved conditions and outcomes for vulnerable communities through actions that reduce the magnitude and extent of the urban heat island. However, some Regions displayed departures from the overall trends, which suggests that the demographic and historical patterns of development are different in these regions and therefore the strategies undertaken to reduce the urban heat island may need to be framed differently to deliver the most effective outcomes.

7.4 Comparison of hot spots and cool spots across metropolitan Melbourne

There were more hot spots than cool spots across the urban area in terms of both the number of features and the total area covered (Table 26).

The Northern and Western Regions had the highest number of hot spots (400+ each), with the largest Average Area (~12 ha), indicating that these are key Regions to focus on for actions to reduce the prevalence of urban heat island hot spots.

The Eastern and Southern Regions had the highest number of cool spots (165 and 380 respectively), as well as the largest Average Area (~10 ha). Preserving these larger consolidated cool spots in these Regions should be a priority.

There were no hot spots located in the Inner South East Region. However, there was a high degree of coverage of urban heat island values of 0-5°C, indicating that these areas are still relatively cool, and providing possible insights into how to maintain low urban heat island values across the Melbourne area. The Inner Region also contained relatively few hot spots, with most of them located in its western half.

Table 26. Number, Average Area (ha) and Total Area (ha) of urban heat island cool spots and hot spots across the Regions, and Total metropolitan area.

	Cool spot			Hot spot		
	No. Features	Average Area (ha)	Total Area (ha)	No. Features	Average Area (ha)	Total Area (ha)
Eastern	*165*	*10.6*	*1754.8*	*55*	*3.0*	*167.0*
Inner	*40*	*5.2*	*209.0*	*20*	*5.0*	*99.8*
Inner South East	*64*	*3.9*	*252.5*	*NA*	*NA*	*NA*
Northern	*47*	*5.6*	*261.4*	*453*	*12.1*	*5476.0*
Southern	*380*	*11.9*	*4529.1*	*243*	*6.6*	*1605.9*
Western	*54*	*3.2*	*174.0*	*401*	*12.7*	*5081.1*
Total metropolitan area	750	9.6	7180.8	1172	10.6	12429.8

7.4.1 Comparison of Demographic Variables between hot spots and cool spots

Density of People

Over the entire Melbourne area, the density of people was similar between hot spots and cool spots. However, there were differences in the densities of people in hot spots compared to cool spots within Regions.

The mean Density of People/ha in Eastern, Northern and Southern Regions was higher in the hot spots compared to cool spots (Table 27). This indicates that urban heat island hot spots may be more likely to coincide with more densely populated areas, where investment and action to reduce the urban heat island could potentially deliver positive benefits to a greater number of people. The exception to this pattern was in the Inner Region, where the hot spots coincided with non-residential land uses, and therefore the mean Density of People/ha was lower in the hot spots compared to the cool spots.

Table 27. Mean Density of People/ha compared between urban heat island cool spots and hot spots across the Regions.

Region	**Density of People/ha**	
	Cool spots (urban heat island < 0°C)	Hot spots (urban heat island > 10°C)
Eastern	*11.5*	*14.3*
Inner	*78.0*	*67.4*
Inner South East	*25.7*	*NA*
Northern	*11.4*	*17.7*
Southern	*11.2*	*13.2*
Western	*15.4*	*16.1*
Total metropolitan area	16.0	16.2

Percent of Dwellings - Rental

The mean Percent of Dwellings that were Rentals was generally higher in hot spots compared to cool spots except for the Inner Region (Table 28). Actions to reduce the extent of these urban heat island hot spots are therefore likely to require mechanisms that provide incentives to land-owners, and some means of positive participation and support from residents living in rental properties. Investment in these actions are also highly likely to deliver additional benefits beyond a reduction in the local urban heat island.

Table 28. Mean Percent Dwellings - Rentals compared between urban heat island cool spots and hot spots across the Regions.

Region	Percent Dwellings- Rentals (%)	
	Cool spots (urban heat island < 0°C)	Hot spots (urban heat island > 10°C)
Eastern	*14.2*	*18.3*
Inner	*35.0*	*25.3*
Inner South East	*22.1*	*NA*
Northern	*16.0*	*23.3*
Southern	*19.4*	*26.6*
Western	*16.7*	*22.5*
Total metropolitan area	18.9	23.5

Average Weekly Household Income and SEIFA Index of Relative Social Disadvantage

Mean Average Weekly Household Income ($) was substantially lower in the urban heat island hot spots compared to the cool spots for all of the Regions (Table 29), and this pattern was also evident in the comparison of mean SEIFA Index of Relative Social Disadvantage (Table 30). This supports previously identified links between urban heat island exposure risks and social vulnerability related to age, ethnicity (Loughnan, et al., 2013) socio-economic disadvantage, and rental status (Urban Forest Consulting, 2018), highlighting the opportunities for reducing the magnitude and inequities in exposure to urban heat island impacts in these regions.

The Western Region was the only one which showed little difference in mean Average Weekly Household Income ($) (Table 29) and a higher mean SEIFA Index of Relative Social Disadvantage in hot spots compared to cool spots (Table 30). This result suggests that the demographic patterns of settlement and urbanization are likely to be different in this region, and the strategies undertaken to mitigate the urban heat island may need to be framed differently for this region.

Table 29. Mean Average Weekly Household Income ($) compared between urban heat island cool spots and hot spots across the Regions.

Region	Ave. Weekly Household Income ($)	
	Cool spots (urban heat island < 0°C)	Hot spots (urban heat island > 10°C)
Eastern	*1503.1*	*778.7*
Inner	*1188.8*	*350.3*
Inner South East	*2008.5*	*NA*
Northern	*2039.0*	*1250.8*
Southern	*1458.0*	*1347.8*
Western	*1284.0*	*1235.5*
Total metropolitan area	1524.1	1228.1

Table 30. Mean SEIFA Index of Relative Social Disadvantage (IRSD) compared between urban heat island cool spots and hot spots across the Regions.

Region	**SEIFA Index of Relative Social Disadvantage (IRSD)**	
	Cool spots (urban heat island < 0°C)	Hot spots (urban heat island > 10°C)
Eastern	*866.8*	*467.2*
Inner	*692.7*	*224.2*
Inner South East	*967.5*	*NA*
Northern	*983.4*	*761.6*
Southern	*969.4*	*874.4*
Western	*580.6*	*690.6*
Total metropolitan area	904.3	737.7

7.4.2 Comparison of Landscape Characteristics between hot spots and cool spots

Percentage (%) Cover of Vegetation

Hot spots and cool spots both contained ~10 to 30% cover of Low Vegetation (Table 31). The Northern, Southern and Western Regions generally contained higher Percent Cover of Low Vegetation in hot spots compared to cool spots, with the Eastern and Inner Regions contained lower Percent Cover of Low Vegetation in hot spots compared to cool spots.

Percent Cover of Tree Canopy was much higher in cool spots compared to hot spots for all Regions, with the mean Percent Cover of Tree Canopy in hot spots being 2.2% for the Total Area, compared to a mean Percent Cover of 44.2% in cool spots (Table 31).

Percent Cover of Total Vegetation displayed similar trends to Tree Canopy, with higher Percent Cover in cool spots compared to hot spots. The exception was the Western Region which displayed higher mean Percent Cover of Total Vegetation in hot spots compared to cool spots, largely driven by the higher mean Percent Cover of Low Vegetation, and the very low mean Percent Cover of Tree Canopy in this region.

The observed trends in vegetation cover between hot spots and cool spots supports the importance of increasing Tree Canopy as a critical action for reducing the urban heat island across Melbourne. While Percent Cover of Total Vegetation is important, the capacity for Low Vegetation to deliver a cooling effect is strongly influenced by the moisture content of the soils and vegetation, and therefore becomes strongly dependent upon supplemental watering programs.

Table 31. Mean Percent Cover of Vegetation in different Height Classes compared between urban heat island cool spots and hot spots across the Regions.

Region	Low Vegetation (<3m)	Tree Canopy (> 3m)	Total Vegetation
Cool spot			
Eastern	*22.6*	*63.2*	*85.8*
Inner	*22.2*	*36.4*	*58.6*
Inner South East	*24.3*	*37.1*	*61.4*
Northern	*11.9*	*72.2*	*84.1*
Southern	*29.1*	*37.5*	*66.7*
Western	*19.1*	*2.9*	*22.0*
Total metropolitan area	26.3	44.2	70.5
Hot spot			
Eastern	*14.6*	*2.1*	*16.7*
Inner	*2.2*	*0.3*	*2.5*
Inner South East	*NA*	*NA*	*NA*
Northern	*22.7*	*1.6*	*24.3*
Southern	*39.2*	*6.1*	*45.4*
Western	*31.1*	*1.7*	*32.8*
Total metropolitan area	28.0	2.2	30.2

Average Annual Rainfall

Mean values of Average Annual Rainfall were higher in cool spots compared to hot spots (Table 32), indicating the importance of background moisture levels in moderating the urban heat island. Prioritizing actions to increase water availability in areas receiving relatively lower rainfall could help to counter these trends.

Table 32 Mean average annual rainfall compared between urban heat island cool spots and hot spots across the regions

Region	Average Annual Rainfall (mm)	
	cool spots (urban heat island < 0°C)	hot spots (urban heat island > 10°C)
Eastern	*864.5*	*820.3*
Inner	*634.3*	*601.1*
Inner South East	*688.6*	*NA*
Northern	*699.2*	*639.2*
Southern	*791.5*	*772.3*
Western	*537.8*	*530.4*
Total metropolitan area	766.1	637.4

Percent Cover of Surface Water

Larger bodies of surface water have a capacity to reduce the urban heat island, as illustrated by the very low mean Percent Cover of Surface Water in hot spots compared with cool spots. This is particularly apparent in the Western Region where the cool spots strongly coincided with larger areaof surface water, such as at the Western Treatment Plant at Werribee (Table 33).

Table 33 Mean Percent Surface Water compared between urban heat island cool spots and hot spots across the regions

Region	Percent Surface Water (%)	
	Cool spots (urban heat island < 0°C)	Hot spots (urban heat island > 10°C)
Eastern	*5.2*	*1.7*
Inner	*18.9*	*0.0*
Inner South East	*3.5*	*NA*
Northern	*5.5*	*0.3*
Southern	*1.7*	*0.5*
Western	*12.8*	*0.1*
Total metropolitan area	4.6	0.3

Planning Zones

Different types of land use display different characteristics in terms of the extent, form and materials used for their built structures and the characteristics of the vegetation. These factors play a major role in determining the temperature of the local urban heat island. Most of the cool spots were characterized by fairly high cover of the Residential Planning Zone Group, followed by Public Land and Roads (Table 34). The exceptions were:

- the Inner region, where cool spots coincided more strongly with Public Land, such as the larger consolidated greenspaces and Special Purpose Planning Zones; and the
- Western Region where the cool spots were more strongly associated with Industrial Planning Zone Group, followed by Public Land and Residential Planning Zone Groups.

Table 34 Representation (%) of Planning Zone Groups within cool spots (urban heat island < 0°C) and hot spots (urban heat island > 10°C) across the regions and total metropolitan area. Planning zone groups with highest proportion cover are in bold.

	Commercial	Commonwealth	Industrial	Public land	Residential	Road	Rural	Special purpose
Cool Spot								
Eastern	*0.6*	*0.0*	*1.4*	*34.1*	***44.1***	*11.8*	*6.3*	*1.7*
Inner	*0.1*	*0.0*	*0.0*	***65.5***	*5.8*	*9.5*	*0.0*	*19.0*
Inner South East	*1.8*	*0.0*	*0.1*	*22.4*	***45.9***	*14.2*	*0.0*	*15.7*
Northern	*1.5*	*1.0*	*1.0*	*35.2*	***51.3***	*8.7*	*0.1*	*1.2*
Southern	*0.5*	*0.0*	*3.6*	*11.5*	***59.0***	*17.2*	*2.0*	*6.2*
Western	*5.5*	*0.0*	***38.9***	*21.2*	*15.0*	*7.4*	*0.0*	*12.0*
Total metropolitan area	0.7	0.1	3.6	20.1	**52.0**	15.0	2.8	5.7
Hot Spot								
Eastern	*17.4*	*0.0*	***55.4***	*11.8*	*4.3*	*5.6*	*0.0*	*5.4*
Inner	*0.0*	*0.0*	*29.1*	*18.9*	*2.0*	*7.1*	*0.0*	***42.9***
Inner South East	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
Northern	*3.9*	*6.6*	*17.2*	*9.5*	***29.7***	*16.6*	*1.2*	*15.4*
Southern	*1.7*	*2.1*	*15.8*	*6.9*	***35.6***	*12.0*	*6.0*	*19.9*
Western	*2.4*	*6.2*	*14.7*	*12.2*	***33.8***	*15.0*	*0.0*	*15.7*
Total metropolitan area	3.1	5.7	16.6	10.4	**31.6**	15.1	1.3	16.2

Most of the hot spots in the Northern, Southern and Western Regions were also associated with relative high cover of Residential Planning Zones, and Industrial, Roads and Special Purpose Planning Zone Groups. In the Eastern Region, hot spots coincided more strongly with Industrial Planning Zones, and in the Inner Region, hot spots were more strongly associated with Special Purpose, Industrial and Public Land Planning Zone Groups.

The strong representation of Residential Planning Zones within both hot spots and cool spots can partly be explained by their relatively extensive cover within the Melbourne area. However, their presence in both the hot spots and cool spots suggests that the characteristics of the Residential areas help determine the temperature of the local urban heat island. Examining the distinguishing characters of Residential neighbourhoods at a finer scale than that of Planning Zone Group could offer constructive insights for how to create cooler neighbourhoods. Similar investigations could also help explain the representation of Industrial, Public Land, Roads and Special Purpose Planning Zone Groups in both cool spots and hot spots providing similar insights into how these types of land-uses can be designed and constructed to minimize the local urban heat island.

7.5 Methods

7.5.1 General patterns of urban heat island across metropolitan Melbourne

The urban heat island data used for this analysis was the 'Land surface temperature and urban heat island estimates for Australian urban centres' dataset from (Caccetta, et al., 2017). To characterize the general patterns of urban heat island values across Melbourne, the urban heat island values were categorised into four groups: < 0°C, 0-5°C, 5-10°C and > 10°C, and the proportion of each group within a feature was calculated. The features used to characterize general patterns were:

1. the extent of the Melbourne Urban Vegetation Height dataset
2. the 2015 Urban Extent (Victorian State Government, 2016)
3. Melbourne Regions
4. their associated Local Government Areas

7.5.2 Urban heat island hot spots and cool spots comparison

Areas within the Urban Extent 2015 dataset that had urban heat island values > 10°C were converted to a polygon spatial data theme in QGIS (Anon., n.d.), and labelled as 'hot spots'. The same process was repeated for areas with urban heat island values < 0°C, which were then labelled as 'cool spots'. All polygons with an area less than 1 ha in size were excluded and all of the remaining features was given a unique identifier within the dataset.

For each cool spot and hot spot polygon, the variables shown in Table 35 were calculated. The mean value for each variable was then summarized for hot spots and cool spots in each of the Regions, and the metropolitan Melbourne area.

Table 35 List of Landscape and Demographic variables calculated to describe the differences between urban heat island hot spots and cool spots across

Predictor Variable	**Source Data and Calculation Method**
Density of People *Indicator of urban intensity*	Mean value calculated from raster dataset using Zonal Statistics. Raster dataset created from 2016 ABS Census measure of Usual Resident Numbers per Statistical Local Area (SLA1), divided by area of SLA1
Percent of Dwellings that are Rented *Indicator of ownership and resident investment*	Mean value calculated from raster dataset using Zonal Statistics. Raster dataset created from 2016 ABS Census measure of Percent Dwelling Rental per Statistical Local Area (SLA1)
Average Weekly Household Income ($) *Indicator of relative wealth*	Mean value calculated from raster dataset using Zonal Statistics. Raster dataset created from 2016 ABS Census measure of Average Weekly Household Income per Statistical Local Area (SLA1)
SEIFA Index of Relative Social Disadvantage (IRSD) *Indicator of access to employment, education and other services*	Mean value calculated from raster dataset using Zonal Statistics. Raster dataset created from 2016 SEIFA measure of Index of Relative Social Disadvantage (IRSD) per Statistical Local Area (SLA1), divided by area of SLA1
% Cover Low Vegetation *Measure of extent of vegetation less than 3.0 m height*	Percent cover calculated by intersecting urban heat island polygon features with Melbourne Urban Forest Structure dataset (features in Height Class 1 and 2)
% Cover Vegetation Canopy *Measure of extent of Tree canopy greater than 3.0 m height*	Percent cover calculated by intersecting urban heat island polygon features with Melbourne Urban Forest Structure dataset (features in Height Class 3,4 and 5)
% Cover Total Vegetation *Measure of extent of total vegetation cover*	Percent cover calculated by intersecting urban heat island polygon features with Melbourne Urban Forest Structure dataset (features in all Height Classes (1-5))
Average Annual Rainfall *Indicator of moisture availability*	Mean value calculated from raster dataset using Zonal Statistics
Percent Cover of Surface Water *Indicator of the terrestrial area available for vegetation*	Percent Cover calculated by intersecting urban heat island polygon features with Surface water dataset created from VMHydro dataset, and VMAdmin Coast_temp.shp
Percent Cover of Planning Zone Groups *Indicator of types of land-uses present*	Percent Cover calculated by intersecting urban heat island polygon features with Planning Zone Group dataset, which included road partition features from CAUL (2018) (Clean Air and Urban Landscapes Hub , 2018)

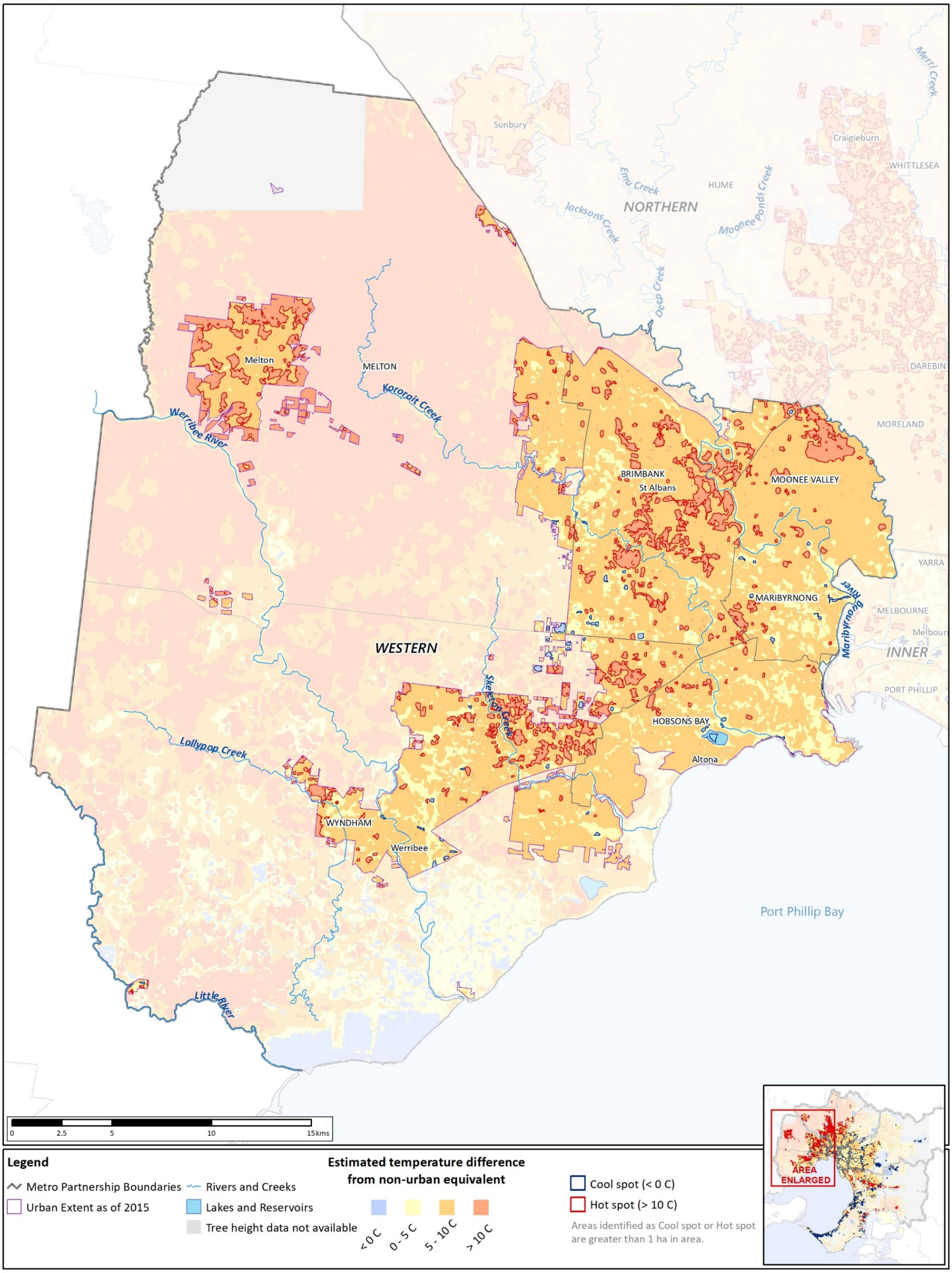


Figure 37 Western Region hot spot and cool spot land surface temperatures

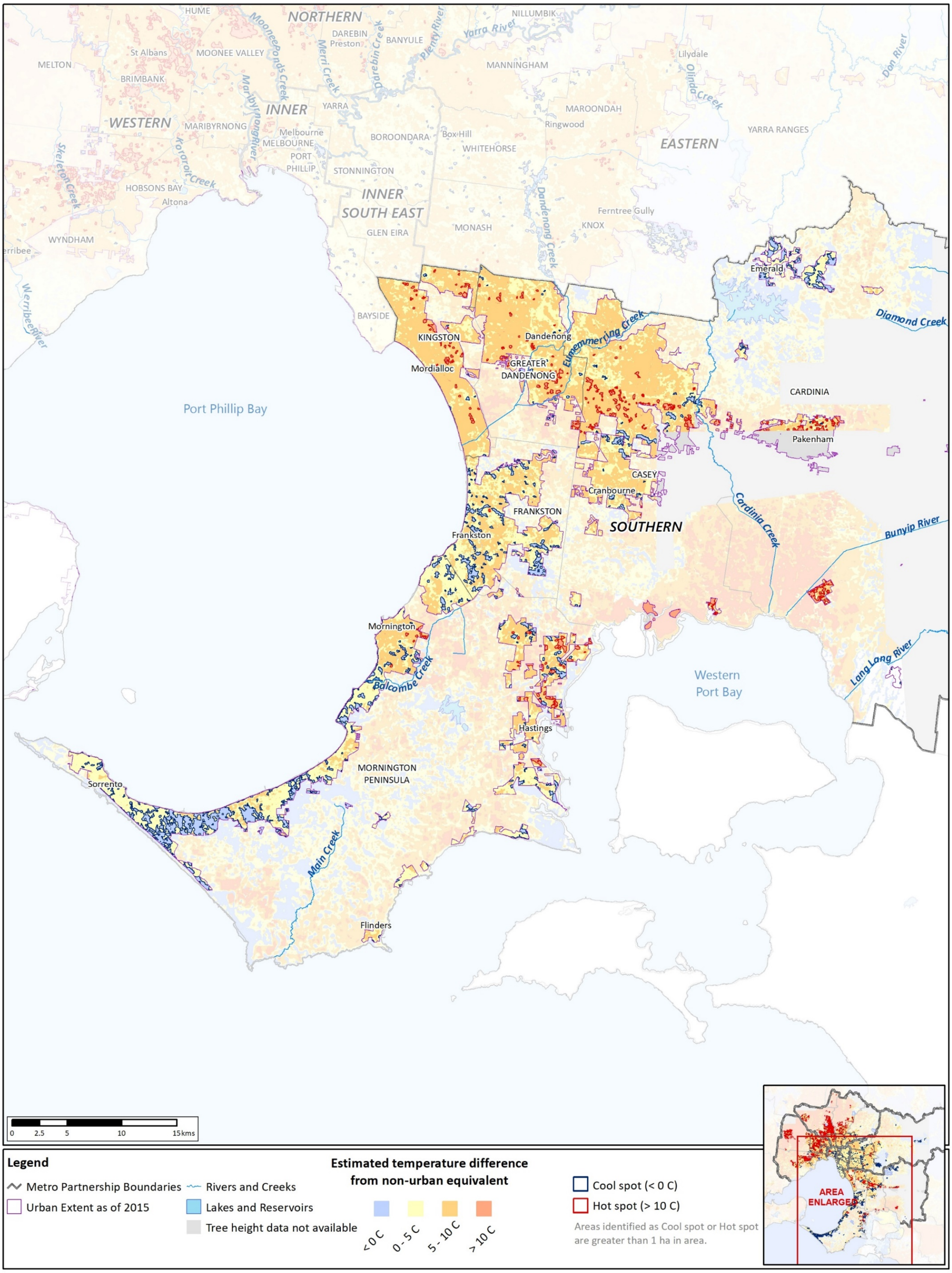


Figure 38 Southern Region hot spot and cool spot land surface temperatures

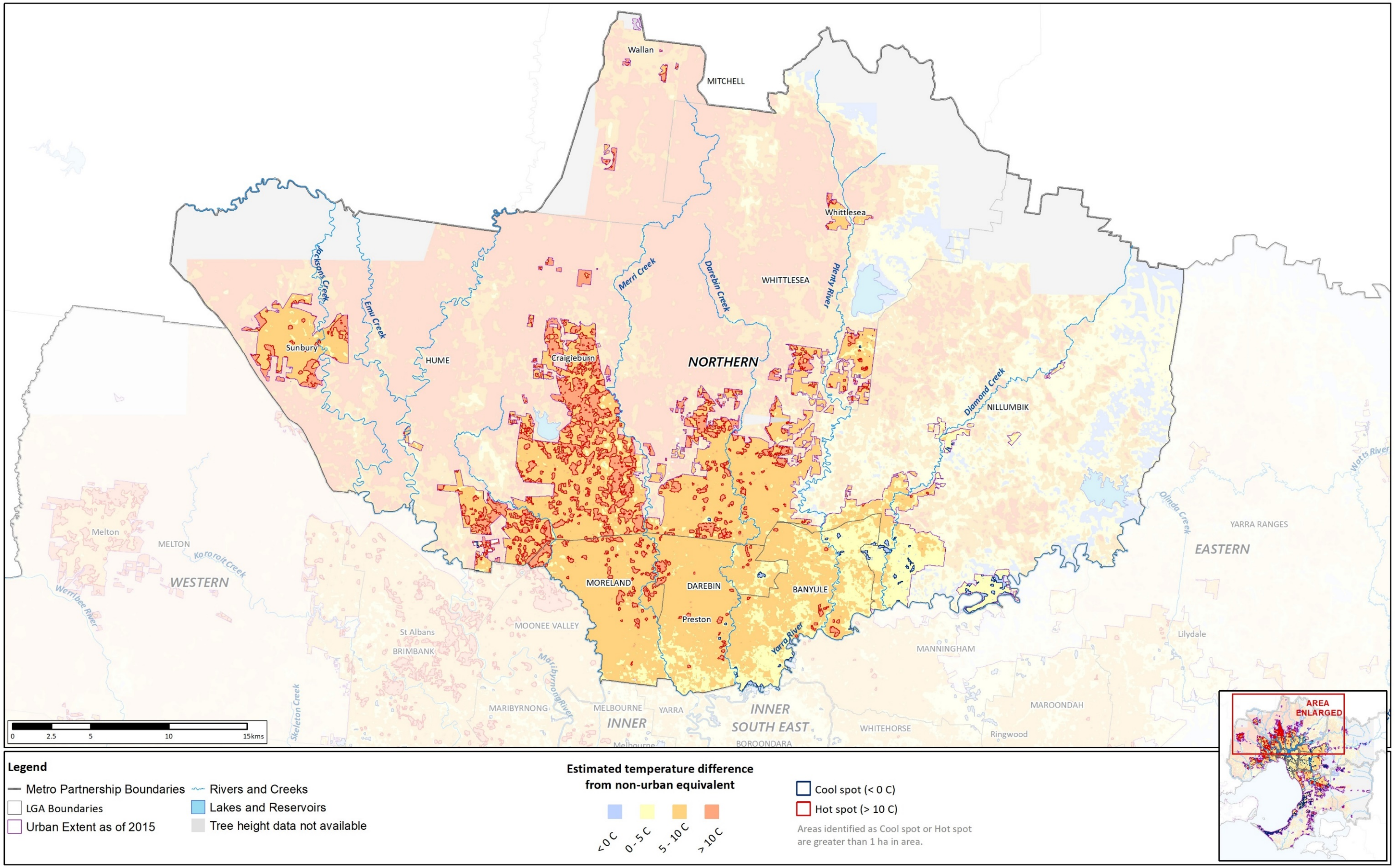


Figure 39 Northern Region hot spot and cool spot land surface temperatures

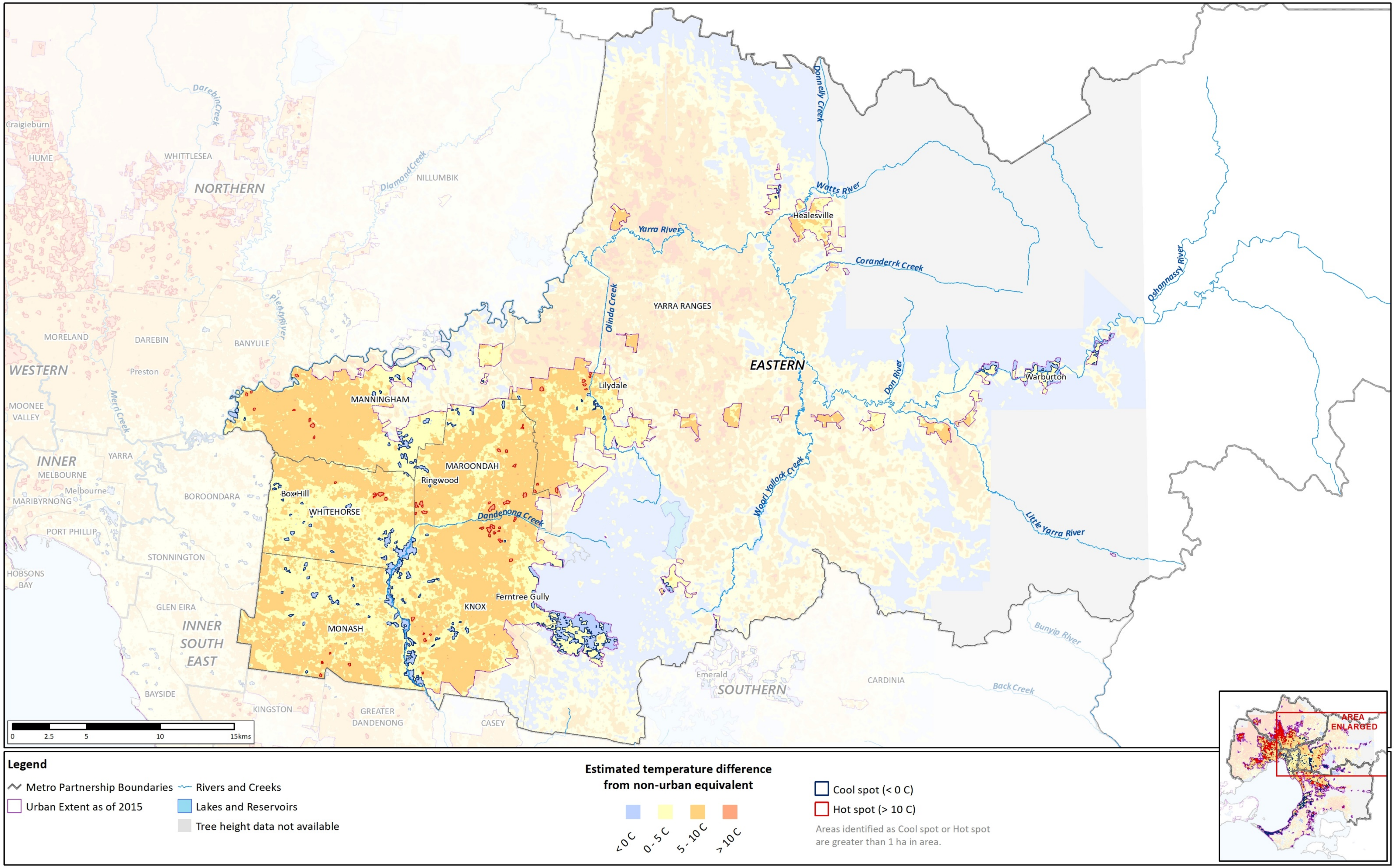


Figure 40 Eastern Region hot spot and cool spot land surface temperatures

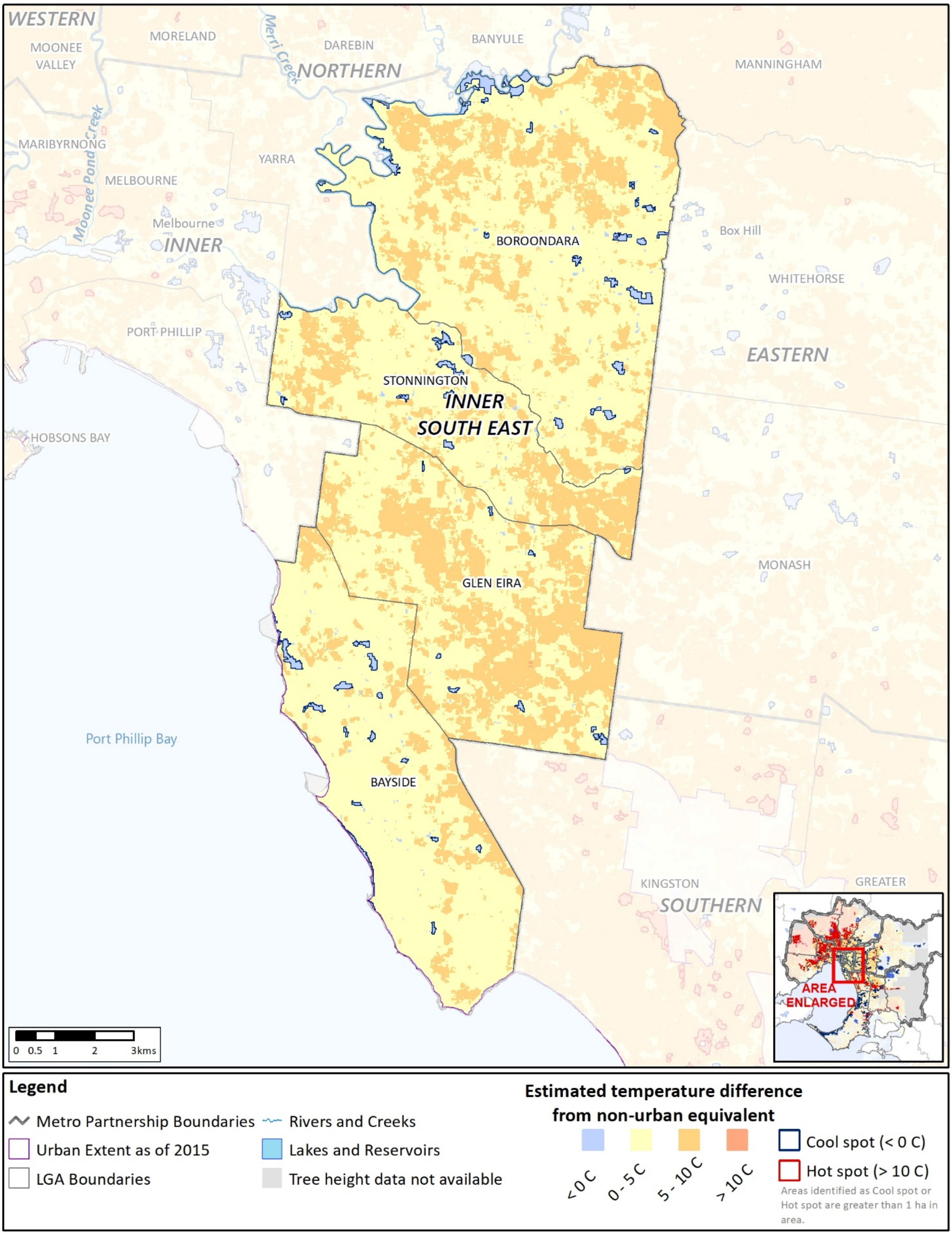


Figure 41 Inner South East Region hot spot and cool spot land surface temperatures

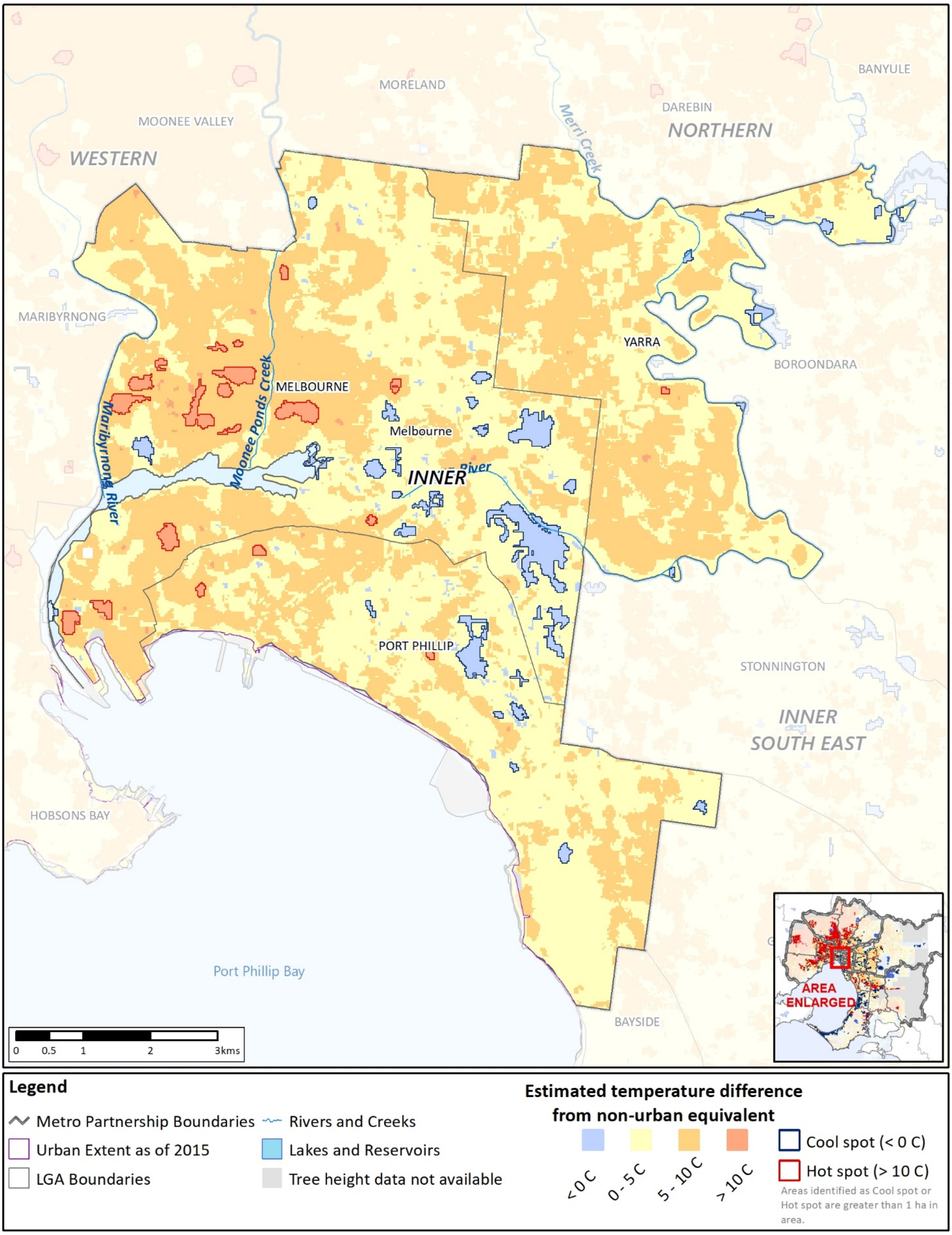


Figure 42 Inner Region hot spot and cool spot land surface temperatures

8 Biodiversity analysis

Melbourne's urban forest is rich in biodiversity. The metropolitan region in its entirety is positioned at the confluence of seven bioregions (broad geographical regions composed of a cluster of interacting ecosystems that share common physical and biological features, such as climate, geology, landforms, soils and vegetation), resulting in a rich mosaic of different plant communities. Most of Melbourne sits in the bioregion of the Gippsland Plain (in the east and south-east), Highlands Southern Fall (in the outer east) and Victorian Volcanic Plain (in the north and west). A total of 93 recognised ecological vegetation classes occur across almost 28% of this land, many of which are endangered or vulnerable. Rivers, creeks, wetlands and swamps add to the complexity and richness of habitats.

Metropolitan Melbourne supports a diverse array of native plant and animal species. More than 2,000 native plant species grow in the Melbourne region. The backyards and streetscapes of our city and suburbs are also home to many plant species that are not native to the region or Australia. Reflecting the significant changes that have occurred in the region since European settlement in 1788, there are 34 species of plants and 52 species of animals that are listed as threatened under the national *Environment Protection and Biodiversity Conservation Act 1999*, and 64 species of plants and 95 species of wildlife listed under Victoria's *Flora and Fauna Guarantee Act 1988* (Victoria State Government, n.d.).

In Melbourne, streetscapes with native trees support significantly more diverse and abundant populations of native birds than do streets with mostly exotic trees (White, et al., 2005). Although many local government authorities maintain good inventories of their street trees, there is no comprehensive picture of street trees across the entire metropolitan area. There is limited data about the trees in our parks and open spaces, and almost no information about the species of trees and other vegetation on privately owned land such as backyards (see 'Opportunities for the urban forest', below). At the neighbourhood level, the highest number of native bird species per hectare is found in native vegetation in parks and reserves. The size of urban remnant vegetation in Melbourne is a major determinant of bird diversity (the larger the area, the greater the diversity) (Palmer, et al., 2008). Large old trees are disproportionate providers of the structural elements (such as hollows, and coarse woody debris) that are crucial habitat resources for many fauna species. But in urban areas these large old trees are particularly susceptible to loss. (Le Roux, et al., 2014).

Most of those natural areas that are located in urban landscapes are fragmented. In order to survive, many species populations must be able to disperse, as this facilitates gene flow. A common conservation approach is to create or improve connectivity by restoring habitat using corridors, stepping stones and buffer zones (Department of Sustainability, 2012). Effective connectivity comprises structural connectivity (physical linkages and proximity of landscape components) and functional connectivity (species movement needs and behavioural responses to the structural connectivity) (Landscape Institute, 2016). Some species may need to move very little, while others may require greater freedom but are constrained by hard barriers such as fences or roads.

Depending on the movement needs of different species, functional connectivity may or may not require physical habitat patch connectivity. Therefore the same landscape will have different levels of functional connectivity for different species. We need to consider connectivity at various scales: local, regional, metropolitan-wide and beyond. Understanding and designing ways to maintain and restore structural and functional connectivity in cities is complex and still in its infancy, although some local government authorities have been working on this concept (O'Malley, 2017). Encouragingly, there are many good examples across Melbourne where the creation of corridors and the restoration of quality habitat have resulted in the return of animal species that are otherwise susceptible to urban development. Hume City Council and Brimbank City Council used the 'guild approach' to determine the connectivity priorities for their Ecological Connectivity Plans. An important part of this work was a series of expert workshops to decide on parameters such as:

- broad habitat types across the council districts and bounding areas (for instance, woodlands, riparian, grasslands)
- the appropriate guilds (groups of species with common attributes) and structural connectivity needs (for instance, species-specific movement capabilities, thresholds, needs, and minimum habitat patch size)
- selection of the focal species for each guild, *highlighted in bold in the table below.* The result of the analysis was a matrix, comprising four main habitats, two dispersal capabilities (longer and shorter relative distances) and 10 focal species. A fifth general habitat for a long disperser was included, to represent species less affected by fragmentation and capable of greater dispersal.

Table 36 Focal species considered and selected (bold) by experts (Source: North-west Ecological Connectivity Investigation 2017)

Habitat	Disperser capability	
	Longer disperser	Shorter disperser
Grassland	Brown Songlark **Fat-tailed Dunnart** Plains-wanderer Red-chested Button-quail Stubble Quail	Australasian Pipit **Golden Sun Moth** Grassland Earless Dragon Little Whip Snake **Striped Legless Lizard** Tussock Skink
Woodlands and forest	**Brown Treecreeper** Agile Antechinus Grey-crowned Babbler	Cunningham's Skink Diamond Firetail Fuscous Honeyeater **Grey Shrike-thrush** **Speckled Warbler** White-throated Treecreeper Yellow-faced Honeyeater
Riparian	Azure Kingfisher Common Ringtail Possum Common Wombat Nankeen Night-Heron **Southern (Large-footed) Myotis** Swamp Wallaby Common Wombat	Eastern Yellow Robin Southern Water Skink **Sugar Glider** Swamp Rat White-browed Scrubwren
Wet habitat	Baillon's Crake Buff-banded Rail Eastern Long-neck Turtle Lowland Copperhead **Rakali**	Brown Toadlet **Growling Grass Frog** Leseur's Tree Frog
Generalist	Eastern Grey Kangaroo **Short-beaked Echidna**	

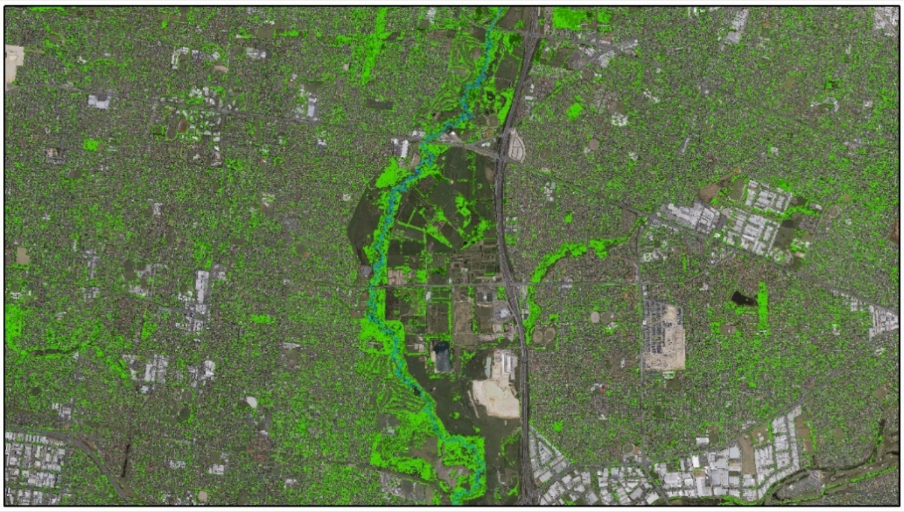
Connectivity and the ability of animals to move, and plants to disperse, within or between patches of habitat is critical for conservation. Many individual patches are too small and widely dispersed to support viable populations. It is therefore important that gardens are not viewed at the individual scale, but instead considered collectively with other gardens and public open spaces as interconnected networks of green spaces across the urban landscape. By extending the urban forest, we can link and create an interconnected matrix of green spaces across our diverse urban landscape.

Using the urban forest canopy cover mapping layer with bird atlas data (supplied by BirdLife Australia) and other important datasets (such as ecological vegetation classes), enables the modelling of different levels of connectivity and landscape permeability for different bird species and bird groups.

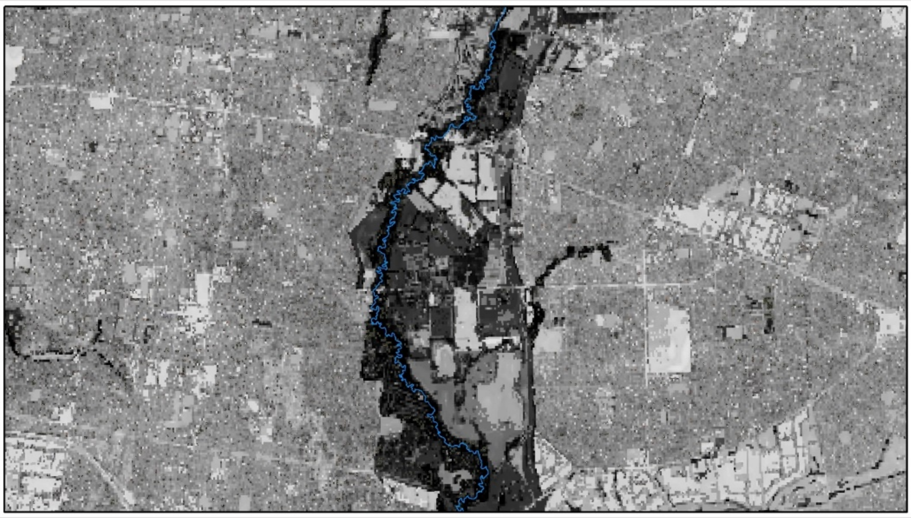
The high suitability of particular riparian corridors (such as along the Yarra River and Dandenong Creek) for many of these species highlights the importance of these features for the persistence of some species in the urban landscape, and the importance of connectivity. However, for species that are better able to exist in the urban environment, suitable habitat and connectivity are also provided by streetscapes and backyards.

Identifying a network of existing and potentially new habitat corridors at different scales for a range of species (and protecting and improving these corridors) will be an important step in creating an enhanced urban forest for Melbourne. For example, by combining habitat models based on species records and known habitat preferences with canopy mapping can reveal areas for future corridor improvement, as illustrated in Figure 43.

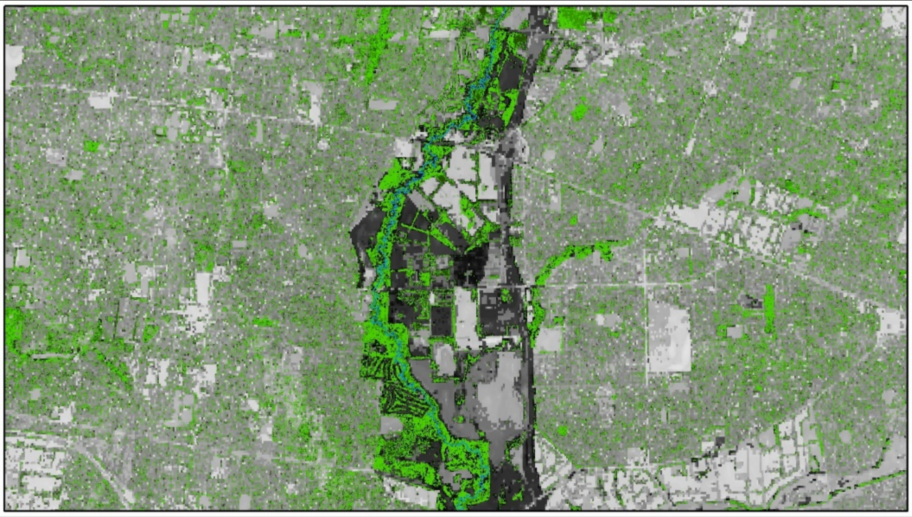
a) Current aerial photography of part of the Dandenong Creek Valley Parklands in eastern Melbourne



b) Mapped canopy cover over the Dandenong Creek Valley and surrounding suburbs over aerial photography



c) Likelihood of occurrence for a suite of hollow-nesting bird species in the Dandenong Creek Valley (black and dark grey areas are most likely) (see also Figure 8 above and the *Living Melbourne Technical Report* for more details).



d) Canopy cover (green) overlayed on hollow-nesting bird species suitability. The areas of visible darkest shading (black and dark grey) indicate areas without existing canopy that could be suitable for restoration and connectivity improvement for hollow-nesting bird species.

Figure43: Canopy mapping and bird species habitat modelling used together, to reveal areas suitable for corridor improvement by expanding the urban forest: Dandenong Creek Valley Parklands in eastern Melbourne

8.1.1 Modelling of bird species or bird group distribution

Modelling of bird species or bird group distribution was undertaken using the Maxent software (https://biodiversityinformatics.amnh.org/open_source/maxent/), and was based on BirdLife Australia's bird atlas (sourced on 10 May 2017) and a range of other datasets (outlined below). The model predicts the likelihood of parts of the urban landscape being suitable for particular bird species or communities, ranging from 'most likely' to 'least likely'.

Data Layers Used

1. Bird Data: The bird survey data was obtained from Birdlife Australia. It was determined that the most suitable dataset that could be validly used for the modelling process (taking into account spatial extent) was the 20-minute, two hectare bird survey point file. This data set had 11,137 bird records from 2,237 sites inside the study area. Other survey data where of a much larger area and/or a transect distance and considered too general for this type of analysis.

This dataset was subsetted to the different species (and one group of species composed of hollow nesters). The following individual species where modelled:

- Superb Fairy-wren
- Eastern Spinebill
- White-browed Scrubwren
- Brown Thornbill
- Eastern Yellow Robin
- Spotted Pardalote
- Noisy Miner
- Musk Lorikeet
- Crimson Rosella
- Eastern Rosella
- Yellow-tailed Black-Cockatoo

The following group of hollow nesters was modelled:

- Laughing Kookaburra
- Owl species (Southern Boobook, Powerful Owl)
- Australian Owlet-nightjar
- Striated Pardalote

2. Digital elevation model: A 30 m digital elevation model for Australia was derived as a subset for the Melbourne area. Data as obtained here: http://www.ga.gov.au/scientific-topics/national-location-information/digital-elevation-data

3. Slope: Slope was derived from the above Digital Elevation Model.

4. Climate data: Mean annual climate data for Australia from 1981 to 2012 was obtained and a subset produced for the Melbourne study area. This data came in the form of a point file grid at a resolution lower than 30 metres; hence a kriging technique was used to resample it to the required spatial resolution. The data was obtained here: https://data.bioregionalassessments.gov.au/datastore/dataset/02418c67-f8bb-48a8-88a3-2a5c6b485f78 (Jones, 2009)

5. Tree data: This came from the vegetation maps produced to inform *Living Melbourne*. The mapping was undertaken using the eCognition Essential software, with the key inputs being 2016 2 metre by 2 metre, eight-band multispectral satellite imagery, and Victorian Government LiDAR information from 2008–2009 to 2012–2013.

6. Melbourne natural vegetation cover/land-use: Two datasets where used in this effort to create the best, latest, and highest resolution data possible – a land-use layer (a) from 2017 and a natural vegetation layer (b) from 2005. This combined layer produced a complete vegetation land cover layer, which was critical for modelling bird species.

(a) The Victorian Land Use Information System (VLUIS) from 2017 was used to obtain land-use classes for the entire Melbourne region (**http://vro.agriculture.vic.gov.au/dpi/vro/vrosite.nsf/pages/vluis**). The following classes where used from LC_desc_16 and combined as follows:

- Urban/Built-up
- Bare
- Agriculture Brassicas/Legumes
- Pasture and Grassland
- Horticulture – Deciduous/Evergreen/non-woody Woody Horticulture
- Softwood Plantation
- Hardwood Plantation
- Water
- Native Vegetation (expanded using natural vegetation land cover below)

(b) The natural vegetation land cover was used to differentiate the native vegetation class. The data used were the older Native Vegetation (2005) - Modelled 2005 Ecological Vegetation Classes (**https://www.data.vic.gov.au/data/dataset/native-vegetation-modelled-2005-ecological-vegetation-classes-with-bioregional-conservation-status**). The eight classes below were substituted into the native vegetation land-use class (#8) above.

The classes where combined as follows:

Wetlands	Riparian/Riverine Grass/Wood/Forests
Salt Tolerant and Succulent Shrublands	Heathlands/Herb-rich/Heathy woodlands
Box Forests/Dry Woodlands/Plains Woodlands	Plains Grasslands/Woodlands
Lowland Forests/Lower Slope Woodlands	Wet/Damp/Rain Forests

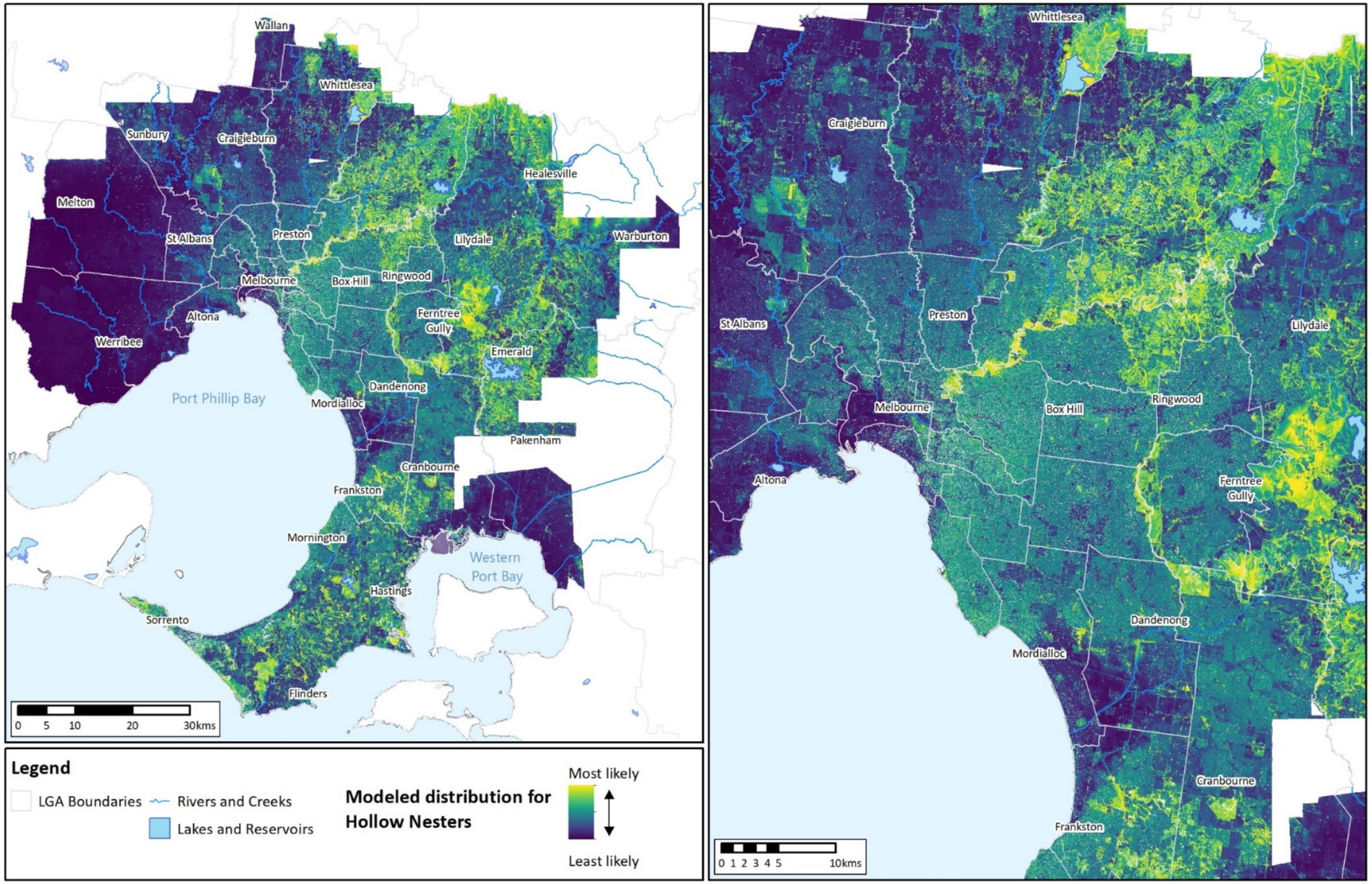


Figure 47 **Modelled distribution for hollow nester species (Laughing Kookaburra, Southern Boobook Owl, Powerful Owl, Australian Owlet-nightjar, Striated Pardalote) in the urban landscape, with suitability ranging from most likely (yellow) to least likely (dark blue) at two scales.**

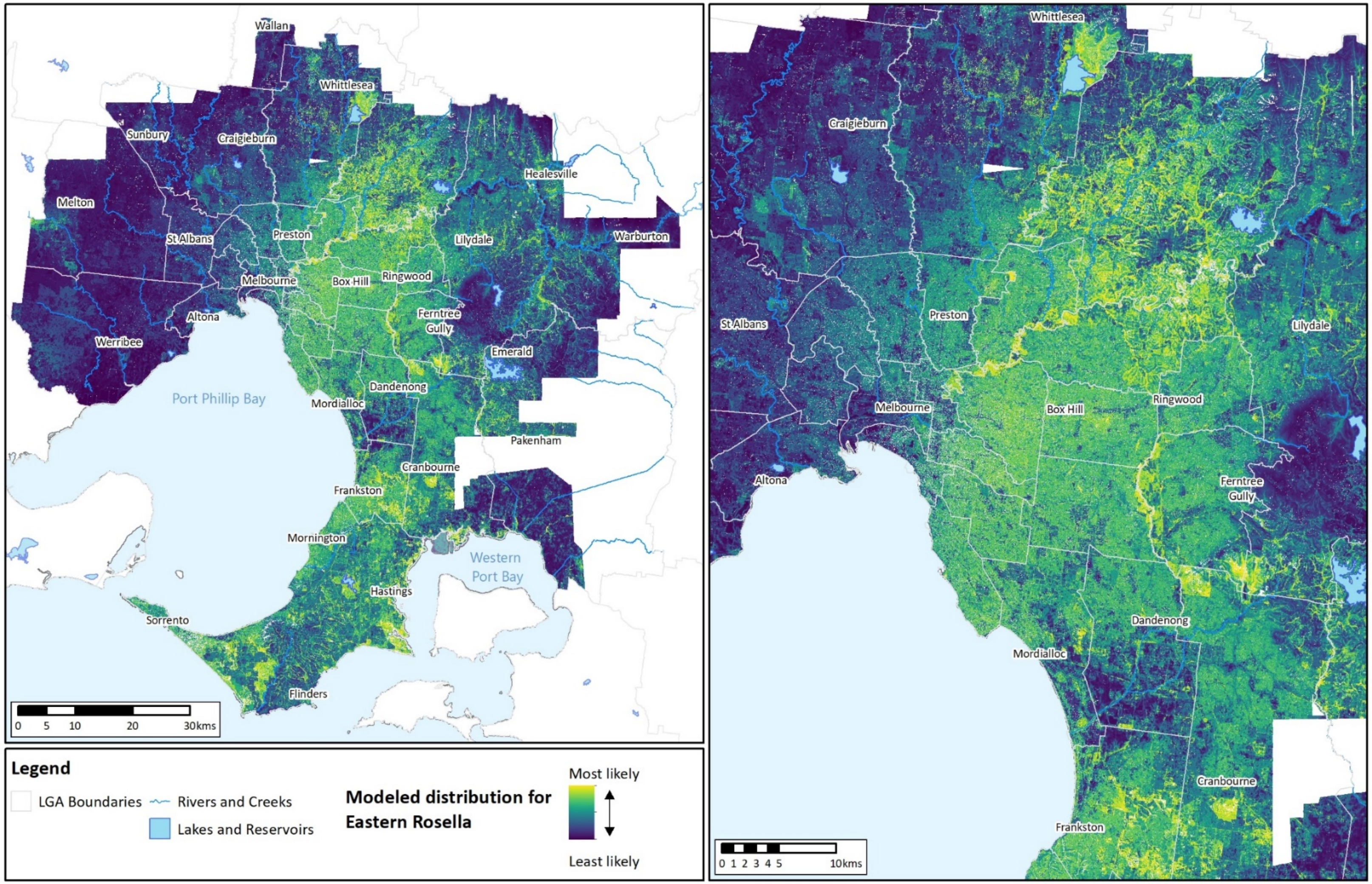


Figure 48 **Modelled distribution for the Eastern Rosella in Melbourne's urban landscape, with suitability ranging from most likely (yellow) to least likely (dark blue) at two scales.**

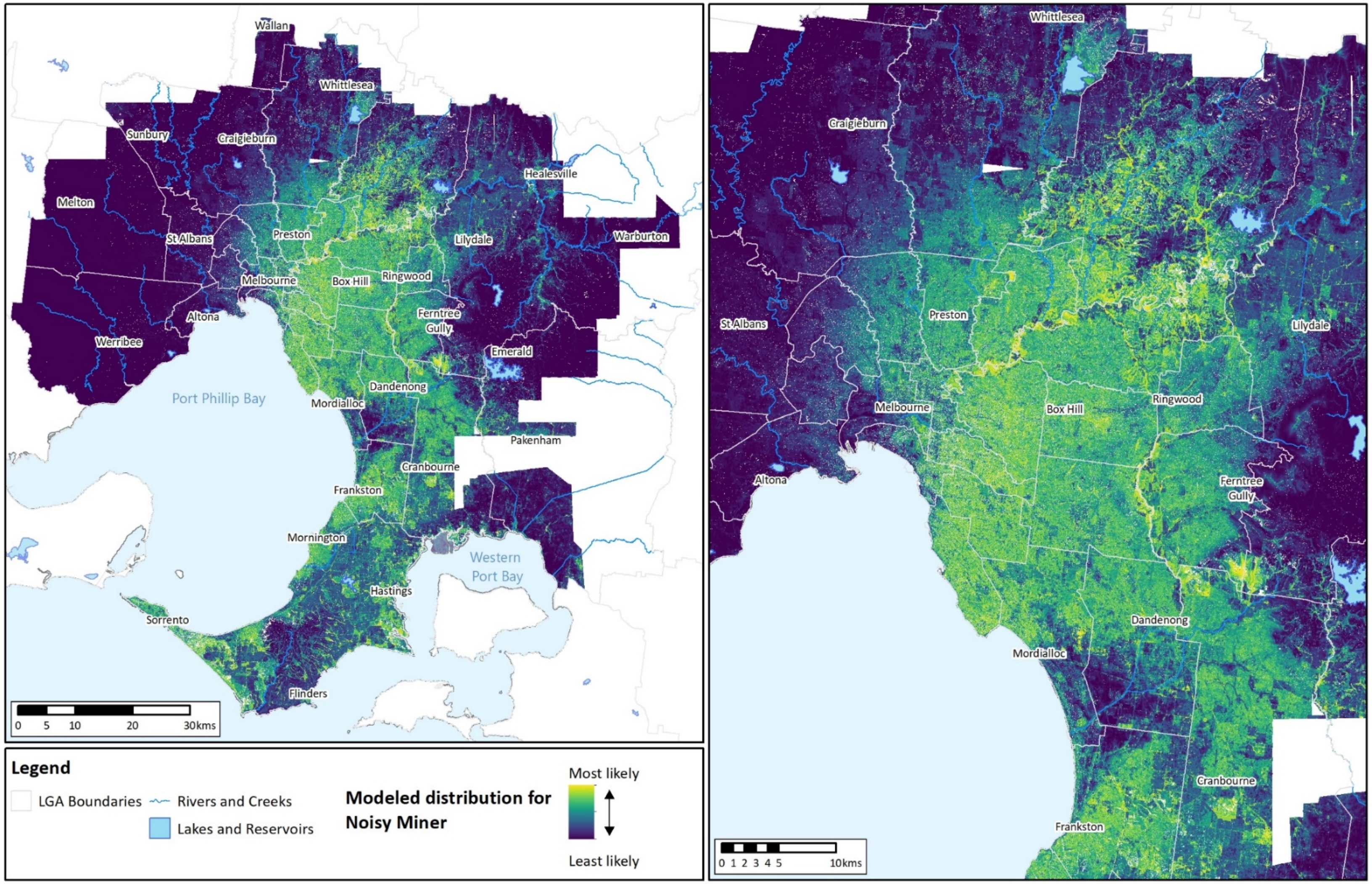


Figure 49 Modelled distribution for the Noisy Miner in Melbourne's urban landscape, with suitability ranging from most likely (yellow) to least likely (dark blue) at two scales.

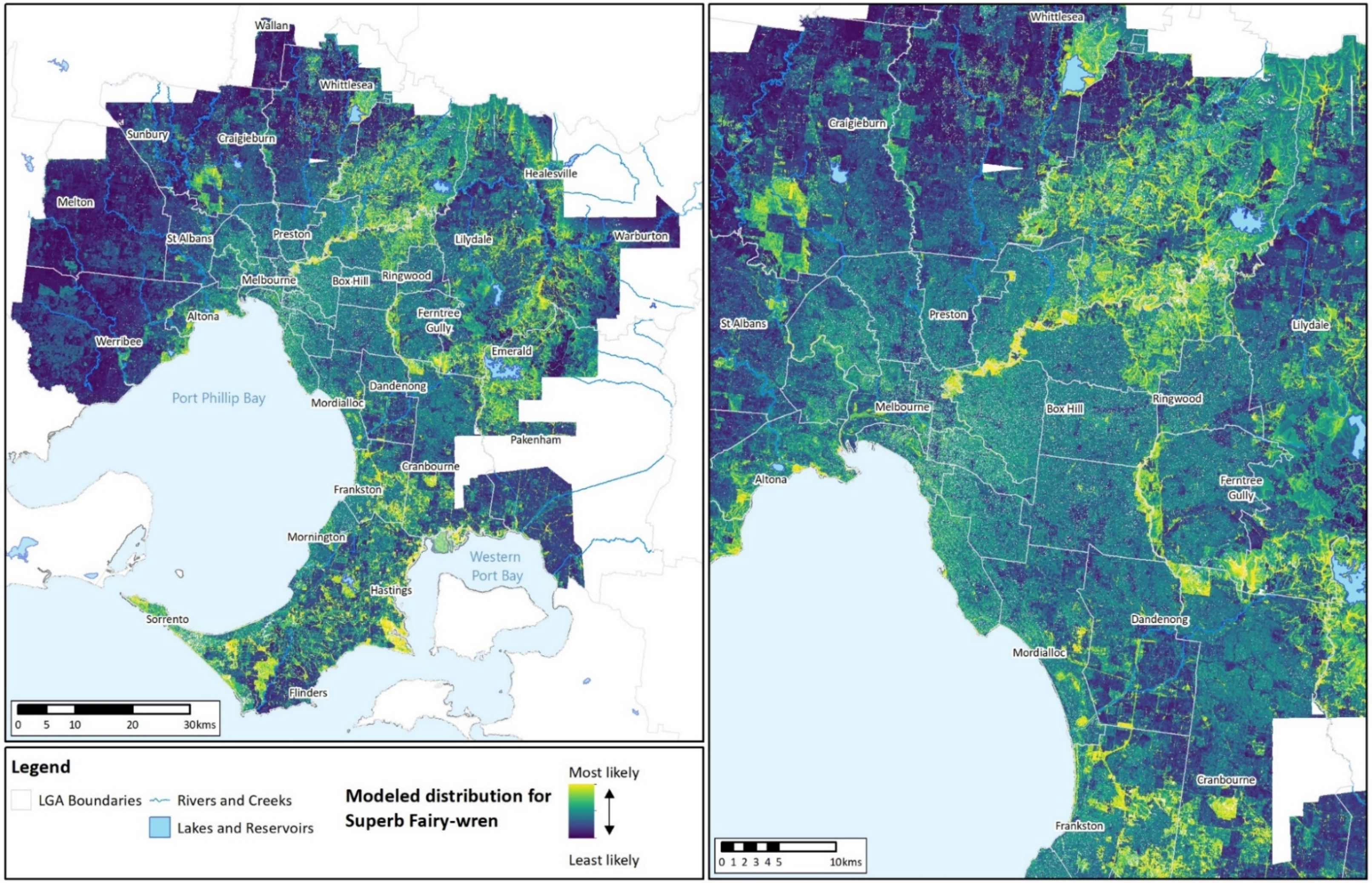


Figure 50 Modelled distribution for the Superb Fairy-wren in Melbourne's urban landscape, with suitability ranging from most likely (yellow) to least likely (dark blue) at two scales.

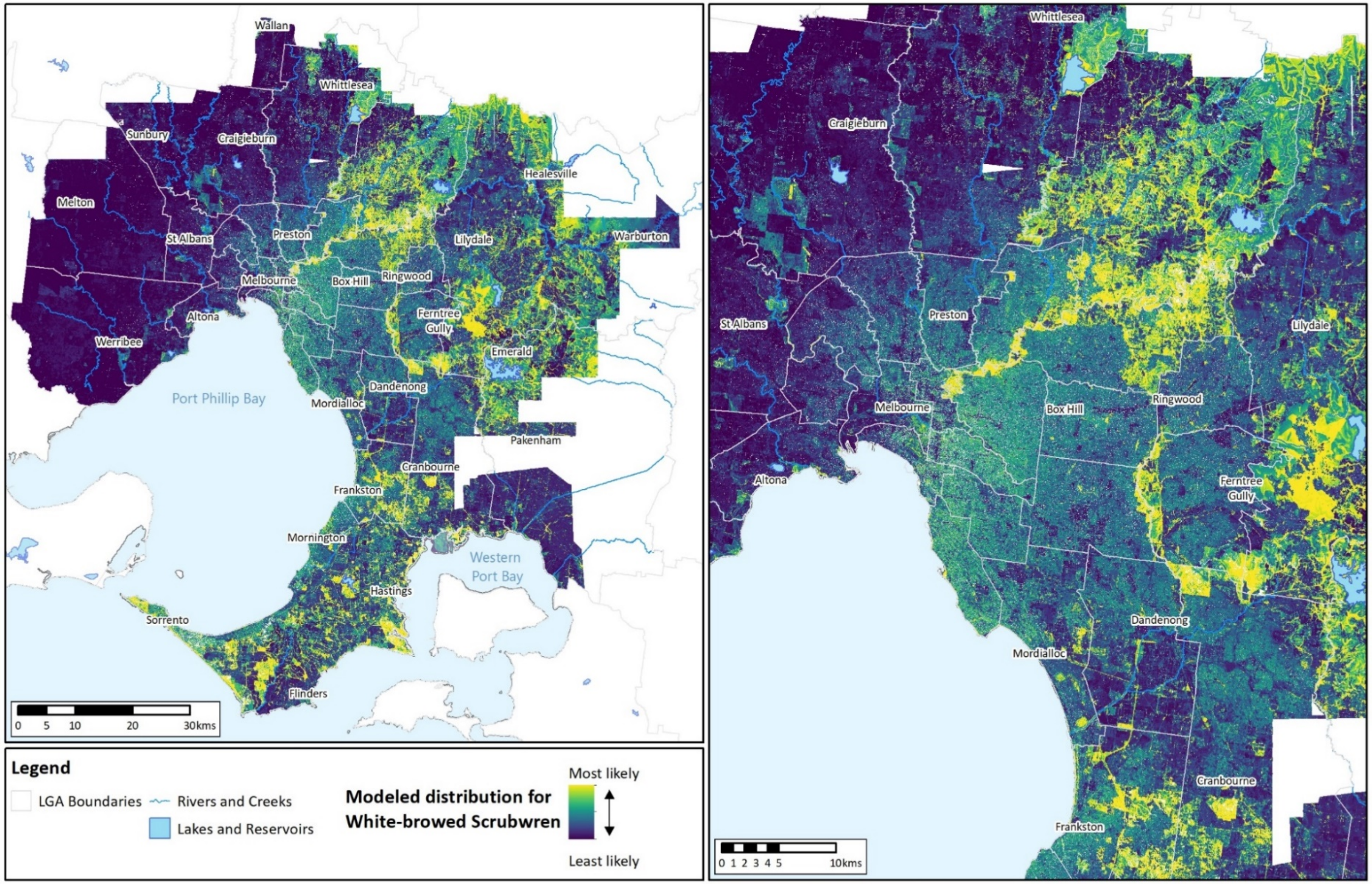


Figure 51 Modelled distribution for the White-browed Scrubwren in Melbourne's urban landscape, with suitability ranging from most likely (yellow) to least likely (dark blue) at two scales.

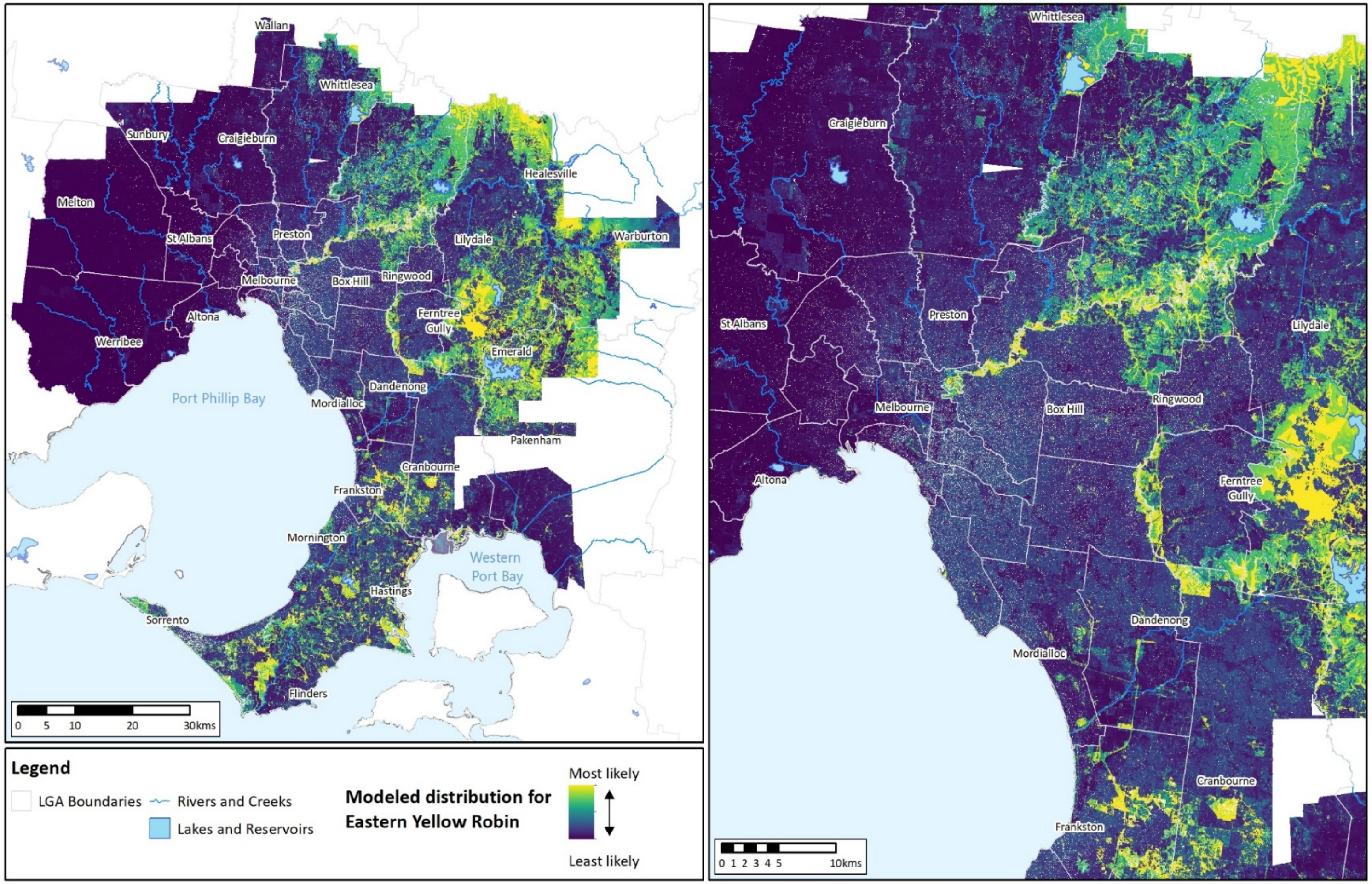


Figure 52 Modelled distribution for the Eastern Yellow Robin in Melbourne's urban landscape, with suitability ranging from most likely (red) to least likely (dark green) at two scales

9 Monitoring, measurement, and metrics

An urban forest plan requires a measuring and monitoring system to ensure that its goals are implemented successfully. A significant component of such a system must focus on the physical urban forest. Measuring and monitoring are two distinct activities: measuring refers to a single activity, such as counting the number of trees at a specific location and point in time, while monitoring relates to repeated measurements with the goal of identifying change. In the long term, repeated measurement of both individual trees and forest sections is vital for understanding the state of an urban forest and for determining the impact of tree planting, husbandry, and stewardship programs. Measuring, monitoring, and maintaining an inventory of urban trees is not a new activity and has occurred for longer than urban forestry has been a discipline (Morgenroth & Ostberg, 2017). However, given the recent technological advances in measuring and modelling, it is now possible to go beyond simple inventory keeping and quantify the many benefits of the forest (Nowak, 2018).

Many diverse stakeholders interact with the urban forest, including citizens, researchers, and government bodies (e.g. transport, planning, environment, and water). These groups require a range of current and historical data for informed decision making. Data such as tree location, height, diameter, and species may be sufficient for the routine care of transport street tree plantings, but park and reserve plantings require information that goes beyond age and health to include provenance, dependent wildlife, and genetic and horticultural data. Given the value of the urban forest services, ecosystem variables are needed for departments that manage the delivery of stormwater services, air quality, biodiversity, and climate change mitigation programs. Last but not least, information such as urban forest management budgets, time, and materials are also required as part of a city's asset and accounting responsibilities. Hence, defining an urban forest dataset that enables strategic progress to be measured needs to incorporate the information that is currently collected, build in flexibility to cater for technological improvements and opportunities, and provide interfaces for the many potential contributors and users.

Urban forest data gathering is a combination of top-down assessments (aerial photography, global positionings systems, light detection, and ranging systems) and bottom-up ground assessments as these provide different types of information. Top-down assessments provide basic metrics on tree cover, distribution, and types. Bottom-up assessments are field-based assessments of the physical structure of the forest (e.g. species, numbers). These assessments can be conducted by citizen scientists, student interns, and trained experts using paper or mobile devices and entering a range of numerical, sketched, and photographic material. Data can be uploaded online and offline. Bottom-up assessments may be done by sampling or as complete inventories, and can be one-off activities or part of an ongoing monitoring program.

9.1 Examples of what is being monitored in metropolitan Melbourne

9.1.1 City of Melbourne Urban Forest Strategy monitoring and measuring

The City of Melbourne Urban Forest Strategy acknowledges that data collection needs to go beyond species, life expectancy, and infrastructure constraints for tree health and include an extensive suite of urban forest structure and impact information. Collected data need to address the six strategic performance targets:

- Increase canopy cover
- Increase urban forest diversity
- Improve vegetation health
- Improve soil moisture and water quality
- Improve urban ecology
- Inform and consult the community

Areas for information development include structural measurements (e.g. canopy cover, density, private and public vegetation, recognition of corridors), physical benefit measurements (e.g. climate amelioration, carbon storage and sequestration, air quality improvements, soil and water conservation), and socioeconomic measures (e.g. outdoor activity, sense of wellbeing, property values, community connection).

9.1.2 Darebin City Council

The City of Darebin 2013 Urban Forest Strategy outlines a range of indicators for measuring the urban forest and strategic progress with its management. Currently, the council collects data on its street trees every two years and is building up a data base of tree health, species, size, structure, and life expectancy. Every five years, a flyover of the council district enables canopy cover measurements to be conducted. Thermal data are collected to assist with measuring the urban heat island effect and to determine where additional trees could be beneficial. The main database is a geographic information system (GIS) that has been modified to log data for each tree.

9.1.3 Boroondara City Council

The Boroondara Tree Strategy 2017 outlines five key performance indicators for its public realm trees. They are the number of trees planted and removed every year, and the canopy cover change, tree age profile, and species tree profile, which are measured every five years. The council also intends to align existing and new tree data with its asset management plan, and to maintain tree data to inform decisions on risk, maintenance, and renewal planning.

9.1.4 Port Phillip City Council

The City of Port Phillip will report every five years on the progress of its urban forest strategy and has highlighted five key indicators. They are the number of hot spots, tree canopy cover, number of trees, community satisfaction with council action being taken about trees, and alternative greening activity (that is, new greening activity where trees are not an option).

9.1.5 Moreland City Council

The City of Moreland’s Urban Forest Strategy 2017-2027 has identified three key performance indicators that will be reported on every four years. They are canopy cover, urban forest health, and community satisfaction with council action being taken to maintain the urban forest.

9.1.6 City of Sydney

The City of Sydney Urban Forest Strategy 2013 identifies four strategic areas for monitoring:

- Protect Existing Forest
- Increase Canopy Cover
- Improve Forest Diversity
- Community Engagement

Along with the associated performance parameter/s and frequency of measurement that varies, depending on the monitoring program element, from annually to every 5 years prior to the review of the urban forest strategy.

9.2 Best Practice for Urban Forest Canopy Targets

Increasing the urban forest results in many benefits. They include managing the urban heat island effect, controlling stormwater runoff, and improving air quality. Regardless of the enhancement sought, increasing canopy cover is a key performance measure (Ordonez & Duinker, 2013). While it is important to set a canopy cover target that will satisfy the objective/s, is ambitious and attainable, there is no universal standard. “Numeric targets are ultimately arbitrarily set, as there is no standard as to what, for instance, canopy cover should be for all cities” (Ordonez & Duinker, 2013).

A commonly quoted canopy cover target is 40%. This target was established in 1997 by American Forests, the oldest national conservation organisation in the U.S. "after analysing the tree canopy in dozens of cities over the [prior] five years and working closely with the research community" (American Forests, 2017). However, American Forests no longer supports a universal 40% target. Rather, the organisation supports a target that is specific to a city and incorporates constraints such as development density, land use, ordinances, and climate. It states that, under ideal conditions, realistic urban forest canopy cover targets across the U.S. are 40-60% in cities in forested states, 20% in grassland cities, and 15% in desert cities. American Forests recently launched their Vibrant Cities Lab website (Vibrant Cities Lab, 2018), which summarises the latest urban forestry research, provides cases studies, and incorporates The Sustainable Urban Forest: A Step-by-Step Approach (U.S. Forest Service and Davey Institute, 2016) guide (Leff, 2016) into an online toolkit.

The first step of the guide is canopy cover. It states that, while there is no magic number for cover as this can depend upon many variables, setting a goal is important.

The Sustainable Urban Forest guide highlights that, while there are many parameters to consider when establishing a canopy target, in reality, political forces or educated guesses often direct the final decision. The guide is based on the premise that more cover is usually better than less (assuming that the cover is adequately maintained), and that setting ambitious targets has the added advantage of providing a simple message to motivate the community and officials and secure funding. The document stresses that the elements that go into setting, achieving, and maintaining the goal are as equally important as the goal itself (Leff, 2016).

The guide also states that the most meaningful measure of canopy cover is 'relative cover'. This means that, after identifying the optimal potential cover based on local parameters (e.g. plantable space, soil type, practical constraints such as maintenance, timeframes), the aim should be to achieve 100% of this level. If a community determines that its tree canopy cover should be 30% and its existing cover is 20%, then the target should be 30%, and progress measured relative to its 20% starting point. A single overarching canopy target may be feasible and simple to communicate and promote, but tree canopy cover does not need to be uniform across a municipality, or even across a neighbourhood. Finer scale analysis by land ownership, watershed, or other land use designations may be more practical. The Chicago Regional Tree Initiative (CRTI) (Chicago Regional Tree Initiative, n.d.) identified the land cover types and available planting space for each of Chicago's municipalities (and subsets of the municipalities) and overlaid constraints such as plant stock availability and time frames to determine targets (Darling, 2018).

A United Kingdom research project undertaken in 2017 by the Institute of Chartered Foresters set out to assess the canopy cover of over 265 towns and cities in England to establish canopy cover baselines. The project provided comparisons with Scottish, Welsh, and international towns and cities, and determined guidelines for setting canopy cover targets to improve human health and wellbeing (Doick, et al., 2017). The review of international targets found that the minimum target was 20%, while a common target was 25-35%. The highest international target was 40% and applied to the City of Melbourne and Toronto. The time frame set to achieve the increased canopy cover was typically 20-25 years. The project notes that, while an assessment of parameters such as plantable space, local context, and geography provides a canopy cover target that is attainable, it does not address whether the cover should be higher to attain overall objectives. A range of other considerations related to canopy targets included establishing deadlines, monitoring, and tree protection programs, and prioritising areas to ensure social equity and maximum benefit.

A 202020 Vision for Australia initiated by Hort Innovation in 2013 aims to create 20% more and better urban green space across Australian cities by 2020. To date, the project has produced several reports, including a *How to Create an Urban Forest Guide* (2015) based on the approach taken by the City of Melbourne. While the Guide stresses that recognising the importance of canopy targets does not assist with identifying an appropriate target, it provides examples of targets set by other cities and municipalities.

Setting goals for private canopy cover is particularly challenging as it directly impacts land development. However, several municipalities have done so regardless. For example, the City of Banyule's goal is to increase canopy cover on non-council managed land by 20% within 15 years, while the City of Moreland's goal is to ensure its current private realm canopy remains at 9%. The City of Wyndham acknowledges the differences between established private realm and new developments and has set two targets: 15% canopy cover for established areas, and 10% canopy cover for new areas by 2040.

An examination of the current urban forest targets reveals that targets can include the following parameters:

- percentage total tree canopy cover
- percentage total vegetation cover (understorey and trees)
- ownership (private land, public land by land manager)
- land use types (e.g. residential, other private, public open space, roads and streets)

The City of Sydney Urban Forest Strategy target is to increase the total canopy cover from 15.5% to 23.25% by 2030, and to 27.13% by 2050. These targets are based on the USDA Guidelines that recommend canopy cover targets for different land uses.

The Nature Conservancy recently released a review that summarised and compared urban forest plans across the USA and internationally (Hinch, et al., 2018). As part of the review, the metrics used to monitor urban forests were considered, and the report identified 23 metrics, both qualitative and quantitative (Table 37).

Table 37 Common urban forest metrics for a range urban forest strategies

	Urban Forest Metric
Quantitative	Number of trees
	% canopy cover
	% canopy cover in neighbourhoods
	% canopy cover by land use
	Rate of change of canopy cover
	% tree diversity
	% potential planting space
	% invasive tree species
	Tree density
	Carbon storage/sequestration potential
	Stormwater capture/filtration potential
	Park acres per 1000 people
	% land as park
	Number of neighbourhoods involved in urban forestry efforts
Qualitative	Existence of and if so quality of urban forest plan
	Existence of and if so quality of urban canopy goal
	Quality of urban forest relative to other regions
	Existence of and if so quality of tree inventory
	Existence of and if so quality of tree species diversity plan
	Existence of and if so quality of tree ordinances
	Existence of and if so quality of comprehensive greening plans
	Types of greening initiatives
	Quality of civic engagement

One of the key recommendations from the analysis was that more research was required to identify which urban forest monitoring, reporting and communicating metrics are most appropriate.

10 Funding and financing mechanisms

Since the establishment of Melbourne as a European-style city, governments at state and local levels, as well as many corporate entities and private citizens, have placed sufficient value on nature and green space within the metropolitan realm to have consistently invested in it. However, it is only in more recent years that people have started ascribing actual financial value not simply to trees, parks, waterways, and other natural elements, but additionally to the kinds of benefits – that is, ecosystem services – that such natural assets provide.

This section highlights some of the funding approaches taken in Victoria to date and outlines more innovative financing mechanisms being implemented locally and round the world.

10.1 Valuation of Melbourne's Urban Forest

To fund any undertaking, it is important to have a clear sense of its value. As has been stated earlier, the metropolitan urban forest is made up of much more than trees alone. However, trees are iconic figures within any forest, and are also by far the easiest flora to value within the urban forest.In the context of the urban forest, communities benefit from public street-, park- and private trees through their aesthetics, recreation, carbon sequestration, air purification, avoided stormwater runoff, and heat reduction (The Nature Conservancy, 2016). Putting an appropriate value on these many benefits is complex, but doing so provides a monetary measure to assist with critical decision making (e.g. care, removal, investment). The United States Department of Agriculture Forest Service has developed a software program "to help communities of all sizes to strengthen their forest management and advocacy efforts by quantifying the structure of trees and forests and the environmental services that trees provide (i-Tree, n.d.)." The software, called i-Tree Eco, has been used extensively within the United States and internationally. End-users include government agencies, universities, and not for profit organisations. More recently, the program has also been adapted for the Australian environment.

While there is currently no total valuation for Melbourne's metropolitan trees, several local councils (e.g. City of Melbourne, Moreland and Banyule) have used iTree Eco to value aspects of their urban trees. More recently, a Melbourne University Masters study attempted to value the benefits of Melbourne's total metropolitan street trees using i-Tree Eco (Mooney, 2018). Incomplete data sets meant that the value of the street trees could be calculated in only 13 of the 32 local government areas. For these 13 local government authorities, the structural street tree value came to A$2.5 billion, based on the replacement cost with a similar tree in terms of size, species, health, and location. In addition, the ecosystem services values calculated included air pollution removal, carbon storage and sequestration, and avoided runoff, and the annual ecosystem services savings were determined to be A$6.2 million.

10.2 What is the value of Victoria's parks?

Parks Victoria commissioned a review of international research into the health benefits of interacting with nature in parks and natural spaces (Townsend, et al., 2015). The report identified over two hundred studies that showed that contact with nature made people physically and mentally healthier.

The key findings of the review included:

- Ready access to parks leads to increased physical activity levels and improved physical and mental health outcomes.
- Parks foster social connections that support social wellbeing vital to urban community cohesion.

- Contact with nature can enhance spiritual health ('meaning in life'), which underpins all other aspects of health.
- Accessible and safe parks foster active play and associated physical, cognitive, and social benefits for children. For older children, parks can improve mental and social health.
- Parks can provide indigenous peoples with vital physical, mental, social, and spiritual health.
- Barriers such as crime, safety concerns, disability access, gender-related concerns, social and cultural norms, proximity/accessibility, weather, and pollution can diminish the potential of parks.
- Better promotion and design help to ensure that parks are accessible, inclusive, and encourage visitation and use by a diverse range of citizens.

As part of the Healthy Parks, Healthy People program, Parks Victoria and the Department of Environment, Land, Water, and Planning (DELWP) used world-leading environmental accounting to understand the value and benefits that parks and their ecosystems provide to the Victorian community.

The study considered:

- The benefits of parks to the economy from tourism, water supply, honey production, and local port management.

  For example:

  - Annual tourist spend on visiting parks was approximately A$1.4 billion.
  - Approximately 16% of the total state water demand is runoff from nine parks. The annual market value of this water was estimated to be A$244 million.
  - Bees in parks and reserves produce around 1200-1600 tonnes of honey worth an estimated annual A$3.4-4.6 million.
  - Parks Victoria manages the Port Phillip, Western Port, and Port Campbell built infrastructure and recreational facilities, with an estimated annual gross value added of A$300 million.

- The benefits of parks to Victoria's productivity and sustainability through water purification, flood and stormwater protection, climate regulation (carbon storage), coastal protection, pollination, and the maintenance of genetic diversity and species.

  For example:

  - In non-metropolitan areas, national and state parks reduce silt entering waterways by 92% when compared with alternative land uses, and metropolitan parks reduce the nitrogen entering waterways by 85% compared to urban development.
  - The value attributed to stormwater retention by Melbourne's metropolitan parks is an estimated annual A$45 million.

- The benefits to Victoria's liveability through recreation and health, landscape and neighbourhood amenity, indigenous cultural connection, social and community cohesion, historic place conservation, and scientific and educational benefits.

  For example:

  - Approximately 50 million visits are made to Victoria's national, state, and metropolitan parks every year, with an enjoyment value of between A$600-1000 million.

- Avoided healthcare costs and productivity benefits from the physical activity associated with Victorian parks is in the region of A$200 million.

A recent study in the United Kingdom (Anon., 2018) calculated an economic value for parks and green spaces in the U.K. The study concluded that the 'wellbeing value' alone, aggregated across the U.K., provided an estimated equivalent benefit of over $A60 billion per year. Compensation to an individual would be in the order of $A1,700 per year to replace the life satisfaction they would have gained from using their local park or green space more than once per month.

10.3 Funding

Funding is an amount of money provided by government or by organisations for an express purpose without expectation of the repayment of capital. The provision of funding is generally based on an agreement to undergo a project or produce a certain outcome for the common good. (Waqar, 2015)

Currently, every council across metropolitan Melbourne funds the protection, creation, and maintenance of vegetation and green space that, in aggregate, contribute to the urban forest. This is among the reasons why the creation of the metropolitan urban forest was the Resilient Melbourne strategy action most supported by councils. Based on data gathering for this project, in the financial year 2017-2018, it is estimated that somewhere in the range of $256 - $384 million – approximately $8 - $12 million per council – were spent on contributions to the urban forest.

In part, this considerable range stems from the lack of a consistent approach to defining contributions. Some council respondents included all spending on open space, while others included only tree planting, maintenance, and contributions focused on specifically agreed urban forest work. Nonetheless, at an aggregated and averaged level, this presents a reasonable estimate of the annual amount local government is contributing to the metropolitan urban forest.

In addition to local government contributions, critical state agencies such as Parks Victoria and Melbourne Water reported collectively funded activities contributing to the metropolitan urban forest in excess of $27 million. This does not include contributions from VicTrack and VicRoads.

However, with some notable exceptions mentioned in Chapter 4, there is little coordination across municipal boundaries and no unified approach to enhancing the urban forest at metropolitan scale. Despite the significant expenditure in the urban forest, only about 40% of metropolitan Melbourne's existing green space and potential forest vegetation is in the public realm. This further underlines the importance of creating mechanisms that either force private contributions, as outlined in Section 5 on planning and legislation, or incentivise it through both existing and potential new mechanisms discussed below.

10.3.1 Victorian Government Sustainability Fund

The Victorian Government's Sustainability Fund was established under the Environmental Protection Act 1970 (Section 70) (Department of Environment, Land, Water and Planning, 2019). The purpose of the Fund is to foster sustainable resource use and best practice for waste management, climate change adaptation and mitigation initiatives across the state.

The Sustainability Fund retains remaining Victorian Municipal and Industrial Landfill Levy (MILL) revenue, after funds are distributed to state environmental agencies such as the Environment Protection Authority and Sustainability Victoria.

In 2017-18, $419 million was provided to Sustainability Fund expenditure over the next five years, a record high contribution from the state budget. This includes sizeable investments throughout Victoria in:

- waste and resource recovery
- climate change adaptation

- biodiversity protection

10.3.2 Renewable energy procurement, storage and National Energy market reformOpen Space Contributions

Open space contributions are a primary source of municipality income, specifically for the purpose of supporting the development, management, and maintenance of new and existing open space. It is levied on new urban development. The open space contribution rate is contained in the Melbourne Planning Scheme's Clause 52.01 (% of undeveloped land value). Funding for open space is also provided through a development contributions plan in the Melbourne Planning Scheme's Clause 45.06. Table 38 provides a comparative analysis of open space contributions between the City of Melbourne and 20 other metropolitan councils based on 2011 population statistics. Contribution rates range from 0- to 20% of the value of undeveloped land. Additional open space and improvements are occasionally delivered through Section 173 agreements between councils and developers. This information is beyond the scope of the planning scheme.

Table 38 Open Space Contribution Rates by Local Government Area

Municipality	Forecast no. of residents 2011	Forecast no. of residents 2026	Forecast change 2011-2026	Forecast % Change 2011-2026	The open space contribution rate contained in the Melbourne Planning Scheme (% of undeveloped land value) *Clause 52.01*	Funding for open space is also provided through a development contributions plan in the Melbourne Planning Scheme *Clause 45.06*
Melbourne	**98,162**	**159,882**	**61,720**	**63**	**None**	**No**
FRINGE AND GROWTH AREA COUNCILS						
Cardinia	76,338	140,526	64,188	84	8%	Yes
Melton	108,839	196,012	87,173	80	3.21% to 9%	Yes
Wyndham	172,101	302,907	130,806	76	2.65% to 3.1%	Yes
Whittlesea	162,067	268,013	105,946	65	8% to 11.3%	Yes
Casey	253,116	359,452	106,336	42	1.61% to 10%	Yes
Hume	175,001	248,409	73,408	42	2.86% to 4.48%	Yes
Mornington Peninsula	150,642	180,258	29,616	20	5% to 12%	No
Nillumbik	63,674	71,442	7,768	12	5% to 7.9%	Yes
ESTABLISHED URBAN AREA COUNCILS						
Yarra	78,592	97,854	19,262	25	4.5%	No
Moreland	152,001	179,186	27,185	18	2.5% to 6.8%	No
Darebin	142,901	166,075	23,174	16	2% to 5%	Yes
Port Phillip	94,736	109,752	15,016	16	5%	No
Maroondah	107,125	120,591	13,466	13	5% to 8%	No
Stonnington	100,537	113,889	13,352	13	2% to 5%	No
Knox	155,620	172,494	16,874	11	5% to 8%	No
Manningham	118,633	131,364	12,731	11	5%	Yes
Monash	175,959	187,298	11,339	6	2% to 5%	No
Whitehorse	155,175	160,803	5,628	4	4%	No
Glen Eira	n/a	n/a			0.25% to 3.5%	No
Greater Dandenong	n/a	n/a			2% to 20%	Yes

Source: Melbourne Open Space Strategy 2012 (City of Melbourne, 2012)

10.3.3 Growth Areas Infrastructure Contribution

Established by the Victorian Government, the growth areas infrastructure contribution (GAIC)aims to help provide infrastructure in growth areas in metropolitan Melbourne's outer fringe (State Revenue Office Victoria, 2019).The GAIC is "a one-off contribution payable onurban development events".The contribution can apply to buying, subdividing and applying for building permits within the contribution area.

https://www.sro.vic.gov.au/growth-areas-infrastructure-contribution

This includes growth area land zoned for urban use and development in the following municipalities:

- Cardinia
- Casey
- Hume
- Melton
- Mitchell
- Whittlesea
- Wyndham

While the GAIC and similar contributions are usually linked to the provision of traditional 'grey' infrastructure, significant opportunity exists to also apply these funds to natural infrastructure. This could contribute to water sensitive urban design and the metropolitan urban forest in outer growth areas, and the multiple benefits these types of infrastructure offer.

10.3.4 City of Melbourne Urban Forest Fund

The City of Melbourne is working to expand its green networks. Through its Urban Forest Fund, the City seeks to engage with the broader community to leave a 'great, green legacy for Melbourne, now and into the future' (City of Melbourne, 2019).

By 2022, the City aims to grow the Urban Forest Fund to $10 million by seeking contributions from other organisations and individuals seeking to promote urban greening within the City of Melbourne.Contributions will be distributed for the purpose of enabling new greening projects including parks, trees and green roofs and walls within the City of Melbourne.

The City of Melbourne has provided $1,000,000 in seed funding to date, with a further $215,000 donated from VicRoads.

10.3.5 Melbourne Water Grants

Corridors of Green Grants Program

Melbourne Water provides grants of up to $20,000 through the Corridors of Green Program to support implementation of projects addressing management of natural resources, in public spaces adjacent to waterways (Melbourne Water, 2017).

The program aims to support, both financially and technically, the conservation and improvement of riparian green space. The improvement of these natural assets will:

- Foster an understanding of waterway health amongst the community
- Promote biodiversity
- Strengthen native vegetation (quality and quantity)
- Provide habitat for returning native species.
- Reduce impacts from processes which threaten the health of waterways

The grants help local councils across Melbourne, as well as public land managers, to improve the health of their waterways and strengthen riparian habitat corridors.

Living Rivers

Melbourne Water also provides funding to councils via the Living Rivers program, designed to fund projects which specifically improve the quality and reduce the quantity of stormwater in Melbourne waterways (Melbourne Water, 2019). Engaging local governments to contribute toward stormwater management is a primary goal of the program, as councils are better placed to attend to the physical landscape at a local scale, and have greater opportunity to connect with the local community.

Grants of up to $300,000 are available twice yearly, to projects including capital works, strategy development and educational programs. Prioritisation is given to capacity building projects which instil Integrated Water Management and Water Sensitive Urban Design principles in standard practice. The Living Rivers program aims to fund projects and programs which continue to support stomwater management beyond the timeline of funding.

10.3.6 National Landcare Program

The National Landcare Program is the primary commitment to natural resource management funded by the Australian Government. Since the 2014—2015 financial year over $1 billion has been invested via four main avenues, the Natural Heritage Trust being the largest (Commonwealth of Australia, 2017).

The National Landcare Program is structured to enable long-term, on-ground planning and investment in natural resource management by engaging communities in land management practices and incentivising industry to contribute to improving natural conditions and promoting the health of waterways, soil and biodiversity.

The funding made available through the grant program supports sustainable agriculture practices and conservation of the local environment, and complements funding for other trusts including the Reef Trust and Land Sector Package. A number of sub-programs exist under the National Landcare Program, which support natural resource management bodies across Australia, as well as contributing to sub-program initiatives such as 20 Million Trees and the Indigenous Protected Areas program.

In 2017—2018, the program provided a total of $5 million to various groups seeking to fulfil the objective of the National Landcare Program: ‘to protect and conserve Australia’s water, plants and animals and the ecosystems in which they live and interact, in partnership with local communities.

20 Million Trees

The 20 Million Trees Program, established in 2014 and operated under the National Landcare Program, aims to partner the Australian Government with the broader community to plant 20 million new trees by 2020. Three rounds of competitive grant allocations were held under the program, providing over $12.4 million combined to communities and organisations to re-establish green corridors and deliver urban forest outcomes at a local level (Australia, 2019).

While funding opportunities aligned with the initiative have ceased, the 20 Million Trees Program remains aligned with other initiatives under the National Landcare Program.

Indigenous Protected Areas Program

The New Indigenous Protected Areas Program is the Australian Government’s commitment to assist indigenous groups in establishing and maintaining Indigenous Protected Areas. A $15 commitment has been made to 2021 and will include the provision of funding for groups looking to establish new areas of indigenous cultural, historical and biodiversity significance across Australia (Australia, 2019). The first competitive funding round under the Program ran from February 2018 to April 2019.

10.3.7 Victorian Landcare Grants

The Victorian Landcare Grant program exists to support Landcare and other environmental volunteer groups in order to undertake land restoration efforts. In 2018, the Victorian Government committed $1.8 million for Victorian Landcare Grants for the 2018-19 financial year (Department of Environment, Land, Water and Planning, 2018).

Applications closed in June 2018, and amounts of up to $20,000 were granted to 363 applicants for on-ground works, education, and capacity-building projects. Additional support and start-up grants of $500 were also made available for new and existing groups.

Grants were open to all Victorian Landcare and environmental volunteer networks that pursued to advance the Landcare ethic. These include, but are not limited to:

- Coastcare groups
- Conservation Management Networks
- 'Friends of' groups
- Landcare groups and networks

10.4 Financing

In contrast to funding, which is provided without any expectation of the return of capital, financing is the provision of capital on the expectation that it is to be repaid over a certain time frame with interest. Financing is usually provided by a financial institution or by investors, and the financed organisations are held liable for repayment under the provisions of the repayment agreement. (Waqar, 2015)

As the cost of assets, including land and nature, has increased globally in recent decades while the cost of capital has generally fallen, there has been a notable move away from simply funding the protection and maintenance of urban parks, street trees, and green space to using financial mechanisms instead. These allow for increased up-front investment, attracting capital from a range of sources, with interest repaid over time. This option allows governments, in particular, to achieve notable outcomes for reduced initial funding.

There are a range of considerations and options for pursuing greening and urban forestry outcomes through innovative financing. An overview of this is presented in Figure 53 below.

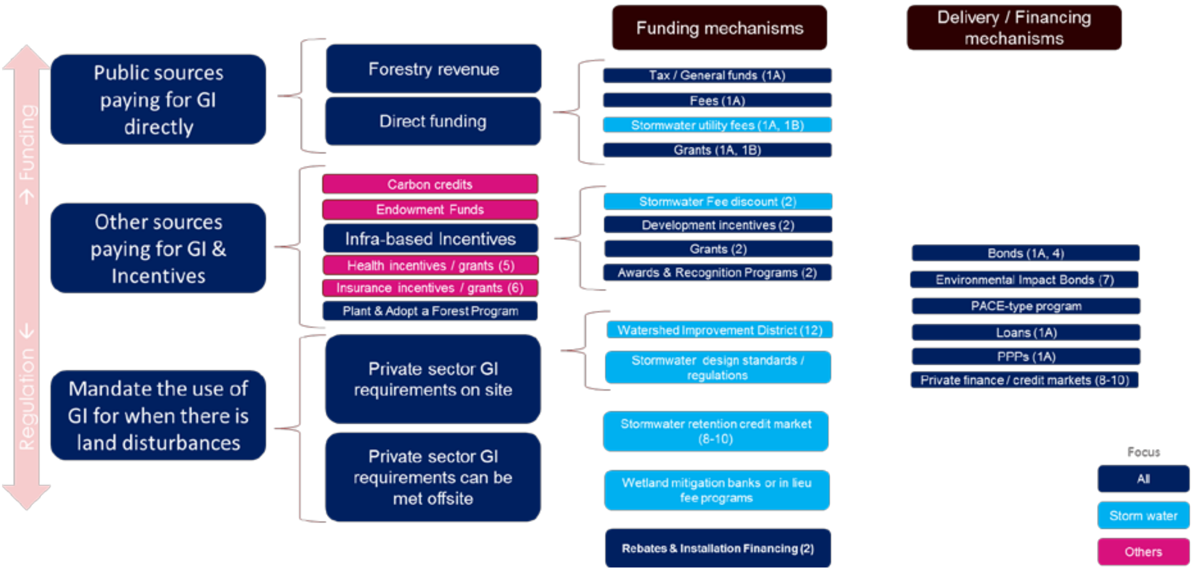


Figure 53 Options for pursuing greening and urban forestry outcomes through innovative financing

The diagram below indicates the types of issues that an urban forest can help to address, making it attractive to financing.

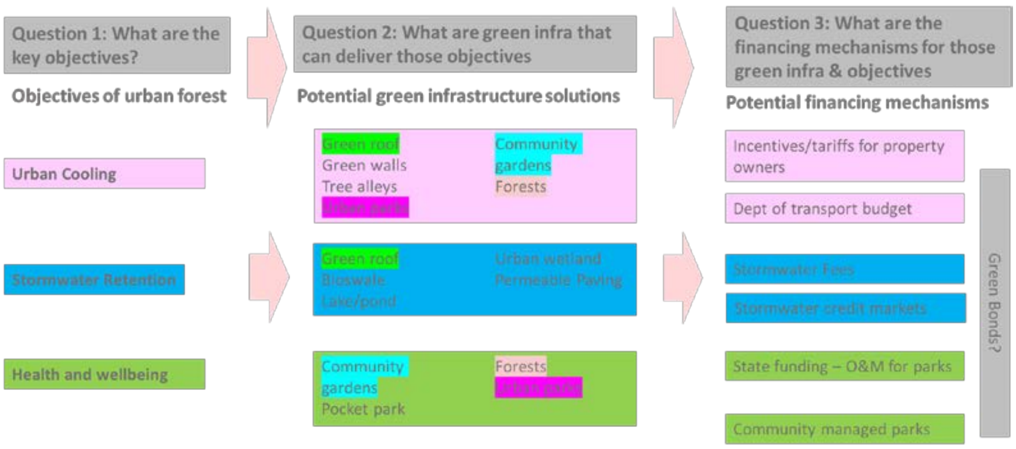


Figure 54 Financial response options to funding the urban forest

10.4.1 Local financing mechanisms

In 2016, the Victorian State Government issued 'green bonds' through the Victorian Treasury Finance Corporation to the total value of $300 million (Victorian Government Department. Department of Treasury and Finance, 2016). Green bonds are used to finance new and existing projects which make efforts to combat climate change, such as low carbon buildings, renewable energies, and water and transport infrastructure upgrades. Victoria has become the first Australian state Government to issue green bonds, and the first state or federal government worldwide to issue green bonds certified with the international Climate Bond Certification.

In their current form, the existing green bonds are not designed to support urban greening and forestry. They also have two further limitations with regards to the work they support: firstly, the bonds requires local government to take on the debt, which many resist; and secondly, they do not direct the outcome towards a shared metropolitan goal. A more specifically designed form of government-backed debt is required to enable such finances to achieve metropolitan wide urban forestry outcomes.

10.4.2 International financing models for environmental and broader outcomes

Below is a list of incentive mechanisms currently being used by municipalities around the United States. The incentives have been organised categorically by type; the following are the primary types of green infrastructure incentives as identified by the United States Environmental Protection Agency (United States Environmental Protection Agency, 2014):

Stormwater Fee Discount: Require a stormwater fee that is based on impervious surface area. If property owners reduce need for service by reducing impervious area and the volume of runoff discharged from the property, the municipality reduces the fee.

Development Incentives: Offered to developers during the process of applying for development permits, to encourage practices which improve water quality and reduce stormwater runoff in urban developments Examples include: zoning upgrades, expedited permitting, reduced stormwater requirements and increases in floor area ratios.

Grants: Provide direct funding to property owners and/or community groups for implementing a range of green infrastructure projects and practices.

Rebates & Installation Financing: Provide funding, tax credits or reimbursements to property owners who install green infrastructure and water sensitive urban design projects particularly in areas most in need of green infrastructure provision, such as those with limited green space or low surface permeability.

Awards & Recognition Programs: Provide marketing opportunities and public outreach for exemplary projects. May include monetary awards.

Some case studies of such financing mechanisms locally and from around the world are presented in the following subsections.

10.4.3 Finance models for metro-wide greening - Portland, OR, USA

Since 1995, the Portland metro region has implemented four funding measures for urban nature projects via voter investments (Oregon Metro, 2019). The provision of 'local share', distributed to the 32 local jurisdictions as negotioated by the jurisdictions, has afforded voters the opportunity to invest in a network of parks and natural spaces. All four measures included competitive grants to fund urban greening at different scales.

Bond measures: A democratic vote approving capital bond measures in 1995 and 2006saw Portland's Metro acquire land, provide funding to community nature projects and parks providers, and protect 13,000 acres of open green space. Local cities and counties have received grants using these bond measures to go towards hundreds of community nature projects across the metropolitan region. The 1995 bond measure raised $136 million to support clean water, healthy habitat and biodiversity, and the 2006 bond measure raiseda further $227 million.

Local option levies: In 2013, voters across greater Portland approved a five-year levy raising approximately $10 million per year to care for the region's parks and trails., supporting restoration and park improvements while also contributing to volunteer programs and community grants. In 2016, citizens voted to approve a five-year renewal of the levy to 2023, raising approximately $16 million per year over the renewed period.

10.4.4 Funding tree planting for public health - The Nature Conservancy

A potential avenue currently being explored to fund urban forestry is to link funding for trees and parks to human health goals and objectives. The impact of trees on particulate matter reduction, alone, is hypothesised to result in health benefits offsetting roughly 13% of the costs of planting and maintatining trees (McDonald, et al., 2017). Air pollution is only one of many observed health improvement pathways provided by nature – others include the promotion of physical activity, refuge from extreme heat, and overall happiness and mental wellbeing from connection with nature.

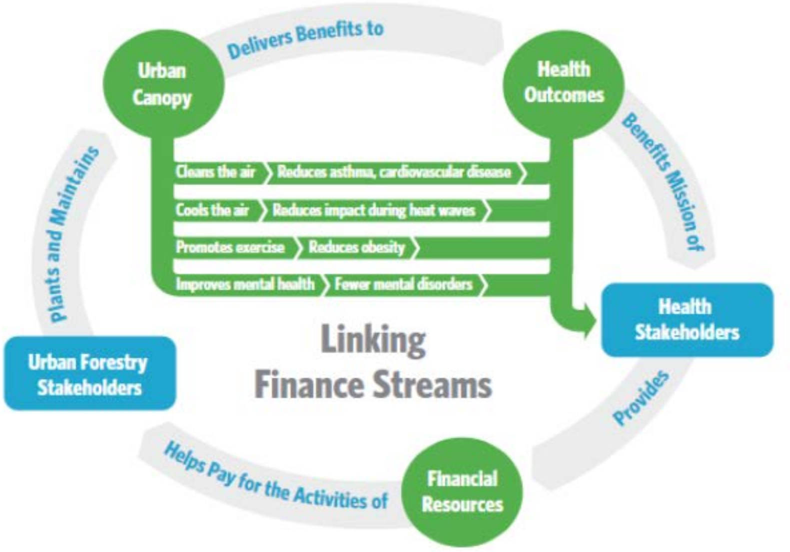


Figure 55 Conceptual model of the linkage between urban forestry funding and health funding (McDonald, et al., 2017)

The concept of linking finance streams for nature and health is straightforward in theory (Figure 52). Funds spent on planting and maintaining trees and other urban vegetation make urban areas greener, in turn delivering significant benefits to both physical and mental health. This aids the health sector to enhance its mission of improving the health and wellbeing of the human population.

It makes sense, therefore, that the health sector could pursue the promotion of the urban forest sector and greater urban vegetation, in order to make full value of the health outcomes of the urban forest. Financial resources put towards urban vegetation by the public health sector may greatly improve preventative health benefits provided by the urban forest, and further strengthen the link between a healthier environment and positive human health outcomes.

10.4.5 Private Markets for green stormwater infrastructure - Philadelphia, PA, USA

Philadelphia's ambitious *Green City, Clean Waters* plan, adopted in 2011, saw the city commit to transforming over 9600 acres of impervious surface area, incorporating green infrastructure designed to capture the first one inch of rainfall from any given storm.

This city-scale plan was determined to cost approximately $2.4 billion USD (equivalent to $250,000 per acre) over its 25 year lifespan, saving billions of dollars over traditional grey infrastructure to produce similar results. However, an even cheaper pathway to achieving the plan's ambitions has been suggested – leveraging private investment and facilitating installation of green infrastructure on private as well as public land, in order to save money for the city as well as taxpayers (Valderrama, et al., 2013).

An analysis in NatLab's "Creating Clean Water Cash Flows" identifies the potential for Philadelphian homeowners to retrofit their residences with green infrastructure and see a return on investment within 4 to 10 years, all the while contributing to the city's stormwater retention capacity. Private investment therefore has the potential to dramatically reduce the cost to the City of maintaining their waterways.

Due to the large variation in costs for green infrastructure retrofits, the analysis by NatLab suggests only low-cost raingardens and bioswales as stable investments to repay residential investors in runoff fee savings within ten years. However, public policies may be used to improve the private market for green infrastructure as well as the payback period for investment while still keeping costs to the City lower than those projected in the *Green City, Clean Waters* plan.

Tools for broadening the market and making investment more attractive include:

- For green infrastructure investment, project aggregation can reduce upfront capital costs through economies of scale
- Credit trading programs throughout the city and offsite mitigation schemes can incentivise private investment in retrofits
- Taking advantage of vacant land for green infrastructure opportunities can be cheaper than retrofits and make land more attractive

Reducing risk for private investment in green infrastructure can be achieved through:

- Reducing regulatory uncertainties (long-term stormwater fee schedule; renewal process for stormwater fee discount; re-approval process and re-approval criteria)
- Reducing project risk (lack of collateral, high transaction costs relative to project size, and lack of a track record) for stormwater retrofit financing repayment

Reducing risk with a loan loss facilityCity-scale investment could also be bolstered through the use of a pay-for-performance structure, modeled on private-public partnerships currently seen in a number of traditional infrastructure projects globally. This may provide significant incentive to invest in some of the more economically appealing retrofits on public as well as private land.

10.4.6 Stormwater Fees and Offsets Melbourne Water

Melbourne Water operates a stormwater offset service, ie. A financial contribution paid by residential developers in order to fund offsite stormwater management projects. These projects are deisgned to offset impacts from stormwater which is unable to be treated within new developments (Melbourne Water, 2018).

A key role in Melbourne Water's operations, stormwater management and waterway health throughout greater Melbourne is achieved by working and engaging with councils, home owners and relevant authorities as well as industry. Melbourne Water also supports developers to ensure receiving waters are protected and maintained, as required by the Victoria Planning Provisions (Department of Environment, 2018).

In developments where compliance with stormwater management requirements is impractical, Melbourne Water offers the flexible offset service to enable developers to comply with the Victorian Planning Provisions. Adopters of a development services scheme who are unable to meet best practice within their development are able to fund stormwater management works offsite either through the offset scheme or as an additional 'stormwater offset' component to their scheme.

Currently, the offset provides funds for capital works only, while Melbourne Water and various agencies fund the ongoing maintenance and operational expenditure of assets. The current rate offered for offsets is $6,645 per kg of annual total nitrogen load; the program and rate are under review.

10.4.7 Green bonds China

Published by the Climate Bonds initiative and China Central Depository & Clearing Co. Ltd (with support from HSBC), the China Green Bond Market 2017 report details China's progress on issuance of green bonds and market growth for green infrastructure (Xiangrui Meng, Alan; Lau, Ivy; Boulle, Bridget; Chen, Sen; Liu, Xiaoyi; Liu, Tianyu, 2018). The second annual flagship report on policy development for green bonds, the report shows a record total green bond issuance of over $37.1 billion (USD) throughout 2017.

A total $22.9 billion USD of this total was aligned with international definitions, and accounts for a total of 15% of green bond issuance worldwide. China, now the second largest green bond market globally, aims to reach $1 trillion USD total in green bond issuance by 2020.

2017 also saw the first greening opportunities idenitified in the Belt and Road initiative, which could attract even further investment into natural infrastructure through green bonds. Over $126 billion USD has been commited to short-term infrastructure projects under the Belt and Road Initiative, marking the importance of natural infrastructure investment in the cross-continental Belt and Road.

10.4.8 'Resilience Insurance'- Quintana Roo, Mexico

Another financial mechanism for biodiversity protection and conservation is through insurance. Collaboration by the Quintana Roo state government in Mexico, The Nature Conservancy and science community partners has culminated in the development of the Coastal Zone Management Trust (The Nature Conservancy, 2018).

The Trust has two roles; It aims to fund the continuous maintenance and ongoing restoration of the coral reef and local beaches of Cancun and Puerto Morelos areas, while also funding an insurance policy for approximately 60km of coast. Triggered when severe weather (wind speeds exceeding approximately 100 knots) hits and damages the reef, the insurance policy will release funds which can then be used to enable restoration efforts to help rehabilitate the reef, and return it to its full protective capacity more quickly, in order to protect the local area's $10 billion tourism economy.

The implementation of this innovative policy will protect a valuable industry and invaluable assets along Mexico's coast, encourage and bolster coastal conservation and ensure a resilient local economy in Quintana Roo – all while creating a new avenue for the insurance industry which may be compatible with other global regions and ecosystems.

Partnership between The Rockefeller Founation and the State Government of Quintana Roo has allowed the execution of the Trust after over two years in development.

10.5 Financial analysis methodology

The financial analysis of *Living Melbourne* is designed to quantify the costs of achieving user-specified, urban tree canopy goals. It is designed as a simple estimate of costs that can be refined as and when more specific and detailed planting plans are available.

The analysis model is contained in an Excel spreadsheet. It is designed so that the user inputs information on the tree canopy target as a percentage of an area. Metropolitan Melbourne is divided into regions (Eastern, Inner, Inner South East, Northern, Southern, and Western), and the tree canopy targets are pre-set at ambitious levels based on parameters such as the climate and the existing (baseline) tree cover of the region (Table 39).

Table 39 Baseline and target canopy cover for metropolitan Melbourne for vegetation heights greater than 3 metres

Region	Baseline canopy cover (% vegetation canopy >3m)	2050 Target (% vegetation canopy >3m)
Eastern	25.2	30.0
Inner	12.5	27.5
Inner SE	21.7	30.0
Northern	12.1	27.1
Southern	16.4	30.0
Western	4.2	20.2

For each council, within each of the regions, the algorithm used in the model calculates the amount of forest canopy cover required to reach the target, and partitions this needed canopy cover across three land-cover types (private, open space, and Crown Road Reserve) in proportion to their area within the council. The importance of this partition is that, as actual greening plans in a specific council or region may concentrate planting in particular land cover types, significantly changing the distribution of new urban forest cover from what is assumed in the analysis model.

The user then inputs the stocking density (stems/ha), and a range of planting costs per stem (low, medium, and high cost scenarios). In the current calculation in the spreadsheet, these values are pre-set at reasonable values based on a review of available data for the Melbourne area (see the 'Planting and maintenance cost base' and 'Stocking density analaysis' below) (Table 40).

Table 40 Stocking density and cost estimates for stems to be planted

Land-use type	Stocking density (stems/ha)	Costs, med. ($/stem)	Costs, low ($/stem)	Costs, high ($/stem)
Private	103	90.00	30.00	156.00
Open Space	71	14.50	13.50	27.00
Crown Road Reserve	109	371.00	236.00	440.00

For each council, the algorithm then simply calculates the total cost of tree planting plus two year's maintenance for planting on open space and Crown Road Reserves. This results in three cost scenarios (low, medium, and high) and three cost estimates generated for each council. These are then summarised by region, or by tree target. If planting costs are assumed to be spread over about 30 years (to 2050), and with some assumptions about likely maintenance costs, capital expenses and operation and maintenance costs over time can be estimated.

It is emphasised that the spreadsheet is merely an algorithm for calculation. It is only as meaningful and realistic as the tree planting targets and cost estimates that users input. For the purpose of *Living Melbourne*, a single target (to 2050) has been applied to the model. However, the model can be amended to accept a range of targets (e.g. low, medium and high) which can be used to test additional cost estimates i.e. three targets and three cost scenarios would result in nine cost estimates for each local government authority and region.

10.5.1 Planting and maintenance cost base

Open Space

It is acknowledged that costs will be affected by parameters such as site-area and local circumstances and needs. The costs assumptions associated with the Melbourne analysis have been drawn from the following sources:

- Council Arboriculture Victoria – a network of local government authority arborists
- A riparian land management organisation
- Personal comments from local government authority open space managers
- Nursery and Garden Industry Victoria

Based on the information from the above sources tube stock are assumed to be used for park / reserve trees, and costs input to the model are inclusive of purchase, planting and two year's maintenance. Additional comparative information was provided by a riparian land manager from example project costs for larger riparian vegetation restoration works.

Cost level	$AUS per unit (tree)
Low cost	$13.50
Medium cost	$14.50
High cost	$27.61

Crown Road Reserve

The Stocking Density analysis was undertaken by The Nature Conservancy using:

- ArcGIS
- The eCognition Essentials metropolitan vegetation mapping developed to inform *Living Melbourne*
- 10cm aerial imagery provided by Victorian Government

Based on the information from the above sources, street trees are assumed to be 45L pots and costs input to the model are inclusive of purchase, planting and two year's maintenance.

Cost level	$AUS per unit (tree)
Low cost	$236.00
Medium cost	$371.00
High cost	$440.00

Private

It is assumed that householders/residents would be planting semi-mature trees rather than tube stock. Figures provided by the nursery and garden industry suggest that most retail purchased trees for private landholders are of the 20-30cm sizing. However, it is also recognised that:

- householders are (almost certainly) purchasing single trees from a retail nursery and that supplementary products (soil, mulch etc.) may add to initial prices (estimated 20%)
- there is a substantial variation in the price of retail nursery trees depending on size, species and vendor

Cost level	$AUS per unit (tree)
Low cost	$30.00
Medium cost	$90.00
High cost	$156.00

10.5.2 The Stocking Density analysis

Undertaken by The Nature Conservancy in September 2018.

Analysis method

The analysis was undertaken on the following three key elements: open space, residential lots and Crown Road Reserves (roads). In summary, the method was to provide multiple examples for each landuse type, measure the canopy area within that area of land and count the stems under that canopy. The canopy data was derived from the eCognition vegetation mapping (August 2018).

Whilst a random analysis was undertaken there were some essential elements that influenced the choice of spaces assessed, including:

- Canopy cover that was representational in terms of that particular spatial area
- Only vegetation >3m was considered as it is difficult to price/cost the benefits of shrubs/small vegetation
- canopy cover that was not contiguous. That is, specific stems could be identified in the landscape. It is difficult to measure the stems of a large bush / forest area such as in a conservation reserve or natural/semi-natural riparian environment.
- Areas where the eCognition mapping software clearly identified canopy cover within a specific area.

Open space

30 reserves were analysed across metropolitan Melbourne Councils

- Parks and reserves (0.5 ha – 5 ha)
- Active Recreation reserves – e.g. where trees are part of the landscape surrounding a sports oval or other recreational facility

The average number of stems per hectare of canopy = 71. The range was from 11 to 185 stems per hectare of canopy cover.

Note: A limitation to the Open Space analysis was that there were larger open space reserves where stems could not be counted because the canopy cover was total (e.g. natural and semi natural open space, conservation reserves, riparian reserves, parks with large patches of forest cover).

Crown Road Reserves

Analysis was undertaken based on the road widths as divided into classes. A ‘road casement layer’ was used to determine the road boundaries and help identify whether a tree stem was within the crown road reserve or on private land.

Various designated classes of roads were analysed from across metropolitan Melbourne including

- Highways
- Arterial and sub-arterial roads
- Local and collector (generally residential) streets

19 roads were analysed in total

The Average number of stems per hectare of canopy = 109. The range was from 29 to 194 stems per hectare of canopy cover.

Residential lots

28 test sites were analysed across metropolitan Melbourne using a variety of spatial areas and numbers of allotments. A sample was taken from 28 municipalities. Stems per hectare of canopy cover were averaged for each residential type.

The Average number of stems per hectare of canopy cover = 103. The range was from 32 to 240 stems per hectare of canopy cover.

11 Tools and resources

Based on feedback received during the development of *Living Melbourne*, Table 41 provides links to 10 tools and resources that may assist practitioners in the protection, enhancement and expansion of the urban forest. These resources are not provided as a definititive list of tools and resources but have been provided as a starting point for practitioners that should be expanded over time.

Tools and resources	Summary description
Built Environment Sustainability Scorecard (BESS) tool	The Built Environment Sustainability Scorecard (BESS) is an assessment tool created by local governments in Victoria. It assists builders and developers to show how a proposed development demonstrates sustainable design, at the planning permit stage. BESS can assess residential, non-residential and mixed-use developments. BESS is designed specifically to support the Sustainable Design Assessment in the Planning Process (SDAPP) framework, providing a consistent and streamlined process for Councils and planning permit applicants. The BESS tool website can be accessed here: https://bess.net.au/
Clearwater website	Clearwater is a capacity building program, recognised for its role in providing programs that equip the water industry with the skills, knowledge and networks to drive the implementation of Integrated Water Management (IWM) practices. The Clearwater website https://www.clearwatervic.com.au/ provides access to training, case studies, research papers and publications, fact sheets, tools, guidelines and strategy.
Embedding Green Infrastructure Best Practice Toolkit – City of Yarra	The Embedding Green Infrastructure Best Practice Toolkit has been developed by the City of Yarra with input from multiple councils to create a tool applicable for all Victorian Local Government. Its aim is to help Council's to assess their own practices against best practice green infrastructure guidance. The toolkit can be accessed here. https://www.yarracity.vic.gov.au/about-us/sustainability-initiatives/embedding-green-infrastructure-toolkit
Greening the West	The Greening the West website proides a selection of links and publications about urban greening. The website can be accessed here: http://greeningthewest.org.au/resources/
How well are we adapting tool	How Well Are We Adapting is a web-based climate change adaptation monitoring, evaluation and

	reporting tool for Victorian local governments. How Well Are We Adapting is being developed for use by all Victorian councils. Currently in 2019-2020, 22 councils around Victoria are members of the tool and are monitoring their responses to climate change. The tool can be accessed here: http://adapt.waga.com.au/
Hydra	Hydra is a web-based mapping tool to enable collaborative integrated water management. Hydra allows authenticated users (DELWP, local government, Catchment Management Authorities and water corporations among others) to add and share information about existing IWM projects and case studies. A link to the hydra website is available here: http://mapshare.maps.vic.gov.au/gvh270hydra/
MUSIC and Melbourne Water's STORM calculator	A model is usually needed during the design of stormwater treatments to help determine the appropriate size and design configuration, and prove that it meets minimum planning requirements. The STORM calculator can be used to model stormwater treatments for small subdivisions, while Model for Urban Stormwater Improvement Conceptualisation (MUSIC) is used for more complex projects.The STORM and MUSIC tools can be accessed here: https://www.melbournewater.com.au/planning-and-building/stormwater-management/storm-and-music-tools
The Clean Air and Urban Landscapes (CAUL) Hub	Research expertise at the The Clean Air and Urban Landscapes (CAUL) Hub covers air quality, urban ecology, urban planning, urban design, public health and green infrastructure, located at the consortium's four partner organisations (the University of Melbourne, RMIT University, the University of Wollongong and the University of Western Australia). The CAUL Hub's research web page is available here: https://nespurban.edu.au/research-projects/
The CRC for Water Sensitive Cities: Tools and Products (TAP) Program	The Tools and Products (TAP) program aims to enable industry adoption and utilisation of key intellectual property outputs from the Cooperative Research Centre for Water Sensitive Cities research, to support mainstreaming of water sensitive technologies and practises. At its core, Tools and Products is concerned with the translation of knowledge into software-based tools. It will create an integrated set of platforms to aid decision-making that will transitions our cities

	towards water sensitive futures. The Tools and Products website can be accessed here: https://watersensitivecities.org.au/content/tools-products-tap/#1510192420464-09fcdea3-1be2 Reference: CRC for Water Sensitive Cities. (2018) *Tools and Products Program.* Melbourne, Australia: Cooperative Research Centre for Water Sensitive Cities.
202020 Vision	The Help Hub of the 202020 Vision provides research and publications developed by the 202020 vision. The website can be accessed here: http://www.202020vision.com.au/help-hub/

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