Priority urban greening analysis

Final report | June 2023

Living Melbourne
Our metropolitan urban forest

MOSAIC insights

NCECONOMICS

The priority urban greening analysis was delivered by Mosaic Insights and Natural Capital Economics for Greater Western Water, Yarra Valley Water, South East Water and Melbourne Water on behalf of Living Melbourne. It builds on work undertaken by Morphum Environmental.

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Contents

Tables

Figures

Summary

Metropolitan Melbourne is growing, with a population expected to exceed 8 million by 2051. The large-scale expansion and intensification of urban development to accommodate the future population is driving the loss of trees, shrubs, and grasses (collectively, the urban forest). As the urban forest declines, the critical habitat for native fauna and the myriad of other benefits the urban forest provides are lost.

At the same time, climate change and changing urban land use means the city is getting hotter, with more frequent, longer and more severe heatwaves impacting human health, productivity, and our way of life. Urban greening is one of the most effective ways to mitigate climate change impacts in cities.

Living Melbourne: Our metropolitan urban forest (2019) identifies that urban greening provides benefits to people:

> *...urban greening improves people's physical and mental health by reducing heat stress, encouraging physical activity, and offering recreational opportunities. Urban greening provides space that encourages physical activity that reduces people's risk of developing chronic heart disease, diabetes, dementia and some cancers. Easily accessible green spaces, trees and nature have positive effects on people's wellbeing, improving their mental health, impacting positively on their happiness. Purely being in the outdoors can be effective in strengthening wellbeing for vulnerable populations.*
>
> *The 'urban heat island' disproportionately affects vulnerable people, including young children, the elderly, people who are unwell or socially isolated, and those who are financially disadvantaged. Targeted urban greening can be used to cool surrounding environments where vulnerable populations are most at risk. (pp. 12 -13)*

In addition, Living Melbourne reinforces the benefits of urban greening to nature and biodiversity:

> *There is widespread recognition that our natural environment is not only beautiful and provides essential ecosystem services, but also that it is fundamental to the health and wellbeing of every Victorian. This understanding is reflected around the world, with an acceptance that nature in and near cities is crucial, not just for maintaining biodiversity but also for ensuring human wellbeing. Although the urban forest provides many services to Melburnians, it is also important to acknowledge that native plants and animals also have significant intrinsic value, regardless of whether they provide tangible benefits to humans. As custodians of the natural environment, it is our duty to protect the biodiversity in our city. (p. 43)*

Targeted investment is required to reverse the decline in urban greening and address the growing challenges of excessive heat and habitat loss.

Our response

Like all significant projects and programs, a major urban greening initiative costs money, and it is important to ensure that the benefits of enhancing urban vegetation exceed the costs. To address this question, Living Melbourne engaged a team of specialists in urban greening, amenity, spatial analysis and environmental economics to:

1. Develop a prioritisation model for urban greening that targeted urban heat reduction and enhancement of biodiversity
2. Estimate the cost to establish and maintain sufficient vegetation to reach desired greening thresholds for different land use categories
3. Identify the benefits provided by enhanced greening for urban heat reduction and enhanced biodiversity, and (where possible) estimated the monetary value of those benefits

4. Undertake a Cost-benefit analysis (CBA) to establish a benefit-cost ratio (BCR) that summarises the relationship between the relative costs and benefits of the priority greening initiative.

A tailored approach was developed to identify high priority areas of metropolitan Melbourne for heat reduction and enhanced biodiversity. The model was based on the Mesh Block spatial scale and was applied to more than 53,000 Mesh Blocks within Melbourne's Urban Growth Boundary. 8,261 Mesh Blocks were identified as priorities for heat reduction and 5,725 Mesh Blocks as priorities for enhanced biodiversity.

The costs of greening the priority areas to the relevant greening threshold was estimated by combining:

- The estimated lifecycle cost of a unit of vegetation (either a tree or a hectare of vegetation)
- The estimated quantity of vegetation required to reach the relevant threshold for greening

The lifecycle cost for a unit of vegetation was estimated using the Tree Costing Tool, which allowed the long-term costs of vegetation establishment (e.g., purchase and planting) and maintenance (e.g., watering, pruning, weed control) for different types of urban greening to be estimated separately. The establishment and maintenance costs were combined to estimate the overall cost over the lifecycle of each unit of vegetation. A summary of the unit cost estimates for different types of vegetation is provided in the table below.

Vegetation type	Priority	Costs		
		Establishment (including purchase and planting)	**Maintenance** (over 30 years) (including watering, pruning, tree mortality etc)	**Total lifecycle costs**
Street tree	Urban heat reduction	$1,113 per tree	$1,485 per tree	$2,598 per tree
Street tree with WSUD	Urban heat reduction	$4,461 per tree	$1,961 per tree	$6,422 per tree
Biodiversity planting	Enhanced biodiversity*	$23,450 per ha	$4,870 per ha	$28,320 per ha

*This example of costs for biodiversity enhancement is to improve site quality from moderate to high quality.

The quantity of vegetation required to reach the greening thresholds in the priority areas was estimated by analysing the current level of greening and the additional trees or area of vegetation needed to reach the relevant greening threshold. This significant spatial analysis exercise included a large area of metropolitan Melbourne (nearly 14,000 Mesh Blocks) at a fine spatial scale.

There is a large body of high-quality evidence that urban greening provides substantial environmental, social and economic benefits. For example, Open Space for Everyone (DELWP, 2021), the Victorian Government open space strategy for metropolitan Melbourne, cited a study that estimated the amenity value for some 12,000 residents immediately adjacent to metropolitan parks in Melbourne to be $21–28 million a year.

Where possible the monetary value of benefits flowing from greening priority areas in this study has been quantified and included in the CBA. The analysis also identified instances where insufficient data was available to confidently estimate the economic value of greening benefits.

CBA is a widely used economic analysis approach to assessing the merits of projects and is the primary analytical tool used in business cases. Using a CBA enables decision-makers to understand the net benefits of enhancing urban vegetation. Importantly, the approach is the same as that used when assessing the benefits and costs of built infrastructure such as a new road or water treatment plants.

Using the inputs described above, a CBA was undertaken for greening priority areas using parameters in line with the Victorian Department of Treasury and Finance. The key findings of the CBA were:

- The dollar value of the benefits of greening metropolitan Melbourne are significant. **For every $1 investment in urban vegetation the benefits return to the community, business and governments across metropolitan Melbourne is around $4** – with a range between a return of $2.16 and $6.70 for every $1 invested. For example, the value of greener streets, with increased visual amenity and walkability (i.e., greater amenity value), is estimated to be $11.8 billion over the next 30 years and the value of carbon sequestration from increased numbers of trees is estimated at $1.2 billion over that period.

	Value (P10 – P90)*
Total costs for greening priority areas for urban heat reduction and enhanced biodiversity	$3.11 B (2.59 – 3.86)
Total benefits	$12.56 B (6.66 – 20.69)
Benefit-cost ratio (BCR)	**4.00 (2.16 – 6.70)**

*Note: Percentiles describe a range that a statistic is within. The 10th (P10) and 90th (P90) percentiles represent the values below and above which 10% and 90% of the results fall respectively. Therefore, the costs, benefits, and BCR ranges presented exclude the highest and lowest 10% of values and provide a robust estimate of the likely range of values. This approach explicitly recognises the uncertainty inherent in a complex exercise such as the priority urban greening initiative.

- The lifecycle costs for the 590,000 trees needed to reduce urban heat and 13,900 hectares of vegetation needed for improved biodiversity where we need them most are significant over the next thirty years. In today's dollars (what the economists call present values), the cost of reducing heat in high priority areas through greening is estimated at $2.2 billion (a range of $1.72 billion to $2.97 billion). Over the same period, the costs of enhancing and protecting priority areas for biodiversity are estimated at $0.9 billion (a range of $0.87 billion to $1.00 billion).
- The prioritisation approach lends itself to breaking these costs down into bite-sized investments to improve health and enhance biodiversity. The large spatial scale at which the cost-benefit analysis was applied (i.e., the entire metropolitan Melbourne area) means it can be improved by finer-scale analysis, local knowledge, and a focus on critical local neighbourhood sites where the benefits will be greatest.

The call to action

The evidence is clear that existing and future investment in urban greening stacks up economically. We should continue and accelerate our efforts to reverse the decline in urban vegetation to address urban heat and protect and enhance biodiversity across the city. Research investment should be considered to address the gaps in our knowledge about the economic value of some important benefits provided by urban greening. Addressing these gaps will improve the accuracy of the benefit valuation, and further demonstrate the value of investing in urban greening.

1 Introduction

The rapid growth and urbanisation of metropolitan Melbourne towards a population expected to exceed 8 million by 2051 is driving the loss of urban vegetation and vital habitat for native fauna. Climate change and urban development mean the city will continue to get hotter, with more severe heatwaves impacting human health, productivity, and our way of life.

1.1 The priority urban greening initiative

Living Melbourne: our metropolitan urban forest (The Nature Conservancy and Resilient Melbourne, 2019) is a bold strategy for a greener, more liveable Melbourne. *Living Melbourne* aims to reverse the current and future decline in the urban forest and sustain Melbourne's liveability for people and nature, across the entire city. *Living Melbourne* was launched in 2019 with 41 endorsing organisations, seven implementation partners and many other stakeholders.

To realise *Living Melbourne's* vision – **our thriving communities are resilient, connected through nature** – in the face of rapid climate change and biodiversity decline, a step-change in funding is needed to accelerate urban greening at scale.

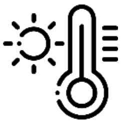
The priority urban greening initiative is an investigation of the net benefits of increased urban greening. An evidence-based approach is applied to:

1. Identify priority areas of metropolitan Melbourne for urban greening to reduce urban heat and enhance biodiversity
2. Establish the costs of greening the priority areas
3. Document and (where possible) quantify the economic benefits of greening the priority areas
4. Apply a cost-benefit analysis to rigorously evaluate the net benefit of greening the priority areas.

The detailed spatial and economic analyses undertaken for this priority urban greening work are documented in this report.

Case studies have been developed for two common greening scenarios – residential streets and commercial centres – to provide a common understanding of the costs associated with the purchase, planting and maintenance of vegetation in these urban contexts. The case studies are provided as an appendix to this report.

The priority urban greening initiative is guided by five objectives that shaped the development and application of the analysis methods set out in this report.

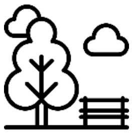


Reduce urban heat

Reduce urban heat for vulnerable communities

Protect and enhance biodiversity

Protect biodiversity and provide enhanced habitat



Enhance open spaces

Enhance priority passive open spaces to cool those places

Improve river health

Improve the health of waterways, riparian corridors and aquatic ecosystems

Integrate with urban water

Identify the intersection with integrated water management opportunities where alternative water sources can be used to support green infrastructure and enhance cooling benefits

1.2 Strategic context

Alignment with *Living Melbourne*

Living Melbourne proposes six actions to help better protect, connect and enhance the urban forest across metropolitan Melbourne. The priority urban greening initiative aligns, in part, with each of the six *Living Melbourne* actions.

Action 1. Protect and restore species habitat, and improve connectivity
Advocates to protect and restore habitats, and increase ecological connectivity of all types between streetscapes, conservation reserves, riparian and coastal areas, open spaces and other green infrastructure across metropolitan Melbourne. This initiative helps facilitate funds to protect and restore habitat and improve connectivity.

Action 2. Set thresholds and track progress
Advocates to set urban canopy and understorey thresholds for each metropolitan region and decide on a clear and consistent method for long-term monitoring and evaluation of the quality and extent of the urban forest. This initiative will aid the implementation of *Living Melbourne* thresholds via a prioritisation methodology and sound business case and improve connectivity.

Action 3. Scale up greening in the private realm
Advocates to strengthen planning and development standards and relevant guidelines to increase the greening of the private realm. Action 3.3 seeks to encourage private landholders to protect and enhance the urban forest and expand greening activities by offering incentives for planting, installing and maintaining natural infrastructure. This initiative helps identify where urban forest professionals can prioritise efforts to assist urban greening in the private realm.

Action 4. Collaborate across sectors and regions
Seeks to encourage collaboration between sectors and regions, to protect and expand the urban forest by strengthening existing regional partnerships, and establishing new ones, and by accelerating greening efforts on private land. This initiative helps prioritise urban greening activity across jurisdictional boundaries, enhancing regional collaboration.

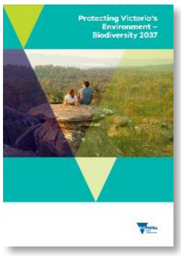
Action 5. Build a toolkit of resources to underpin implementation
Seeks to equip practitioners to protect and enhance the urban forest by building on existing resources and creating a shared toolkit to facilitate implementation of best practices. This initiative progresses Action 5.1 to build the capacity of public and private sector practitioners to protect, enhance and expand the urban forest and Action 5.2 to build on, and develop new tools for public sector land managers.

Action 6. Fund the protection and enhancement of the urban forest
Aims to establish a set of funding and financing options to suit different types of urban forest action. This initiative will provide an evidence-based business case of prioritised on-ground action that will be available to all stakeholders to use in support of urban greening funding bids.

Alignment with other strategies

Plan Melbourne 2017–2050 sets a strong policy direction towards cooling and greening, to help create a city that is more sustainable, resilient and better adapted to the changing climate. This project aligns with Action 91 and 93 of Plan Melbourne by supporting cooling and greening Melbourne and '20-minute neighbourhoods' by creating cool routes for people to walk and cycle.

Victorian Public Health and Wellbeing Plan 2019–2023 sets the direction and provides a framework for coordinated action. This initiative supports this Plan by prioritising and costing urban greening so that people of all ages are afforded the opportunity for optimal health and wellbeing so they can participate fully in their community, in education and/or in employment.



Protecting Victoria's Environment – Biodiversity 2037 is the Victorian Government's plan to halt biodiversity decline and improve the state's natural environment. It highlights the need to create more liveable and climate-adapted local communities by planting trees to reduce heat and creating a network of natural and designed green spaces. This initiative aligns with the Biodiversity 2037 goal 'Victorians value nature'. This goal is better achieved if people in urban Melbourne have access to excellent conservation reserves.

Healthy Waterways Strategy 2018–28 covers the rivers, creeks, estuaries and wetlands of the Port Phillip and Westernport region, providing a single framework to protect and improve the waterways' environmental, social, economic and cultural values for the community. By enhancing the extent, connectivity and biodiversity of urban forests, as well as strategic alignment between the objectives of urban cooling, biodiversity and integrated water management, the initiative supports the vision of the Healthy Waterways Strategy 2018.

Victoria's Climate Change Strategy is a roadmap to net-zero emissions and a climate-resilient Victoria by 2050. This initiative supports this strategy by advocating for and prioritising place-based adaptation with special emphasis on vulnerable communities, improving how we consider climate change when making decisions about the built environment and taking immediate steps to minimise the urban heat island effect.

Greater Melbourne Regional Climate Change Adaptation Strategy outlines key priority action areas for people, businesses and communities of Greater Melbourne to address the unique challenges and opportunities that climate change brings and guide locally relevant practical action. This strategy identifies increasing and enhancing the natural environment, urban green spaces and parks as a key action area to help buffer urban heat and other extremes. It also strongly supports enhancing urban biodiversity.

2 Project approach

Understanding the required investment and the benefits that will flow from greening priority areas across the nearly 3,000 km^2 area of metropolitan Melbourne is a complex task.

2.1 Overview of the approach

An approach was developed that drew on spatial analysis of Victorian Government urban tree canopy data sets, the latest information on greening costs, published research into the benefits of greening, and widely accepted economic analysis methods.

Priority areas for greening for urban heat reduction and enhanced biodiversity were selected using a variety of spatial data sets (see Appendix A for details). The priority areas were identified on the basis they have the greatest need for increased greening to reduce urban heat and enhance biodiversity. The prioritisation approach was applied at the Mesh Block spatial scale, which allowed priority parcels to be identified at a local scale, but also provides the flexibility to aggregate the results up to neighbourhood, suburb or Council area.

Box 1. What is a Mesh Block?

Mesh Blocks are the smallest geographic areas defined by the Australian Bureau of Statistics (ABS), each containing approximately 30-60 dwellings based on census data. In areas with high population density (e.g., apartment blocks) there may be more than 60 dwellings in a Mesh Block. The area of each Mesh Block varies – in inner city areas with higher population density they have a smaller area compared to peri-urban communities or rural areas with lower population density and consequently larger Mesh Block areas.

Each Mesh Block is assigned to a land use category based on the broad identification of land use such as residential, commercial, primary production and parks.

More information on Mesh Blocks can be found on the ABS website.

The **number of trees and plants** for each priority Mesh Block was estimated using ambitious but achievable thresholds of greening. Detailed spatial analysis identified where and how many additional trees could be established in streets and open spaces for heat reduction and the number of plants needed for priority biodiversity areas.

The **lifecycle costs of establishing and maintaining vegetation** were estimated using the Tree Costing Tool, an economic modelling platform developed by Natural Capital Economics and Mosaic Insights on behalf of Horticulture Innovation Australia with inputs from urban vegetation experts from the public and private sectors across Australia. Using the outputs from the spatial analysis, the Tree Costing Tool provided the range of likely investment costs for the different priority areas. The Tree Costing Tool is available from the Hort Innovation website.

The **benefits of urban greening** were identified through a literature review and (where possible) valued using an ecosystem services framework and widely accepted economic valuation methodologies.

A **cost-benefit analysis** (CBA) was used to compare the long-term costs and benefits of greening using parameters in line with the Victorian Department of Treasury and Finance. This approach is the preferred method for assessing major public expenditure decisions and enables decision-makers to understand the net benefits of asset investments. Importantly, the approach is commonly used to assess the benefits and costs of built infrastructure, such as a new road or a water treatment plant upgrade. Applying the CBA approach in this study allows investments in urban greening to be compared to investments in more traditional asset classes.

The approach is illustrated below (Figure 1) and described in more detail in the following sections.

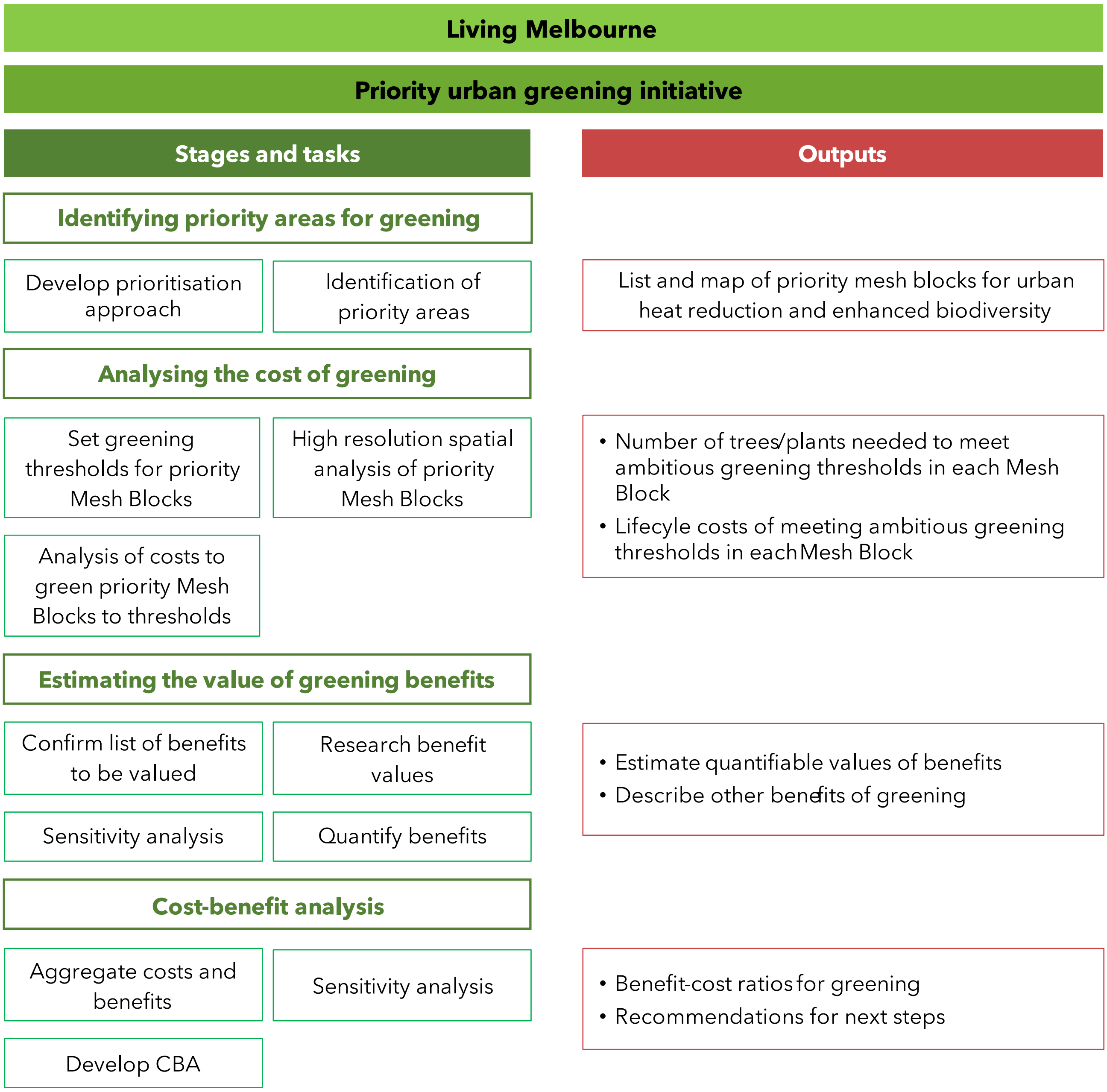


Figure 1: Overview of the priority urban greening analysis approach

2.2 Identifying priority areas for urban greening

The prioritisation approach

An approach was developed to prioritise Mesh Blocks for urban heat reduction and enhanced biodiversity. Mesh Blocks within Melbourne's Urban Growth Boundary were included in this analysis (53,358 Mesh Blocks in total). The prioritisation approach calculated a score for each Mesh Block for heat reduction (the urban cooling score) and enhanced biodiversity (the biodiversity score). The approach, data inputs and scoring system differed for heat reduction and enhanced biodiversity priority areas, as described below.

The urban cooling score highlights Mesh Blocks with a high need for heat reduction to protect vulnerable communities. The focus is on passive open spaces, local community and education facilities. The data sets used to calculate the score are shown below (Table 1 and Appendix A).

Table 1. Data sets used to prioritise Mesh Blocks for urban heat reduction.

Data set	Description	Data source
Hotspots	Metropolitan Melbourne Urban Heat Islands and Urban Vegetation 2018	https://www.planning.vic.gov.au/__data/assets/pdf_file/0018/440181/UHI-and-HVI2018_Report_v1.pdf
Tree canopy / vegetation cover	Metropolitan Melbourne Urban Heat Islands and Urban Vegetation 2018	https://www.planning.vic.gov.au/__data/assets/pdf_file/0018/440181/UHI-and-HVI2018_Report_v1.pdf
Heat vulnerability	Metropolitan Melbourne Heat Vulnerability Index 2018	https://www.planning.vic.gov.au/__data/assets/pdf_file/0018/440181/UHI-and-HVI2018_Report_v1.pdf
Open space	Victorian Planning Authority (VPA) Open Space data set	https://discover.data.vic.gov.au/dataset/open-space
Pedestrian exposure	Melbourne Industrial and Commercial Land Use Plan Commercial – Existing Vicmap Features of Interest (details available here) Victorian Railway Stations (details available here)	https://discover.data.vic.gov.au/dataset/melbourne-industrial-and-commercial-land-use-plan-commercial-existing11

The biodiversity score identifies Mesh Blocks with the highest potential to contribute to improved habitat protection, restoration and connectivity for a variety of species. The focus is on existing open and green spaces, with increased weighting given to natural and semi-natural spaces and conservation reserves.

The Victorian Government developed specialised decision support tools that bring together the best information available, to help inform how we prioritise land management actions that protect the future of Victoria's unique plants, animals, and habitats. One of the data sets available in the Strategic Management Prospects decision support tool is the Biodiversity Value Rank. This was developed from the Strategic Management Prospects revegetation benefit model (developed by the Department of Energy, Environment and Climate Action (DEECA)) that predicts the benefits of suitable revegetation to 4,200 species and preferences connectivity. This data set was used as it spatially prioritises beneficial revegetation actions at a state level.

The data sets used to calculate the score are shown below (Table 2 and Appendix A).

Table 2. Data sets used to prioritise Mesh Blocks for enhanced biodiversity (all accessed in November 2022)

Data set	Description	Data source
Tree canopy / vegetation cover	Metropolitan Melbourne Urban Heat Islands and Urban Vegetation 2018	https://www.planning.vic.gov.au/__data/assets/pdf_file/0018/440181/UHI-and-HVI2018_Report_v1.pdf
Open space	VPA Open Space	https://discover.data.vic.gov.au/dataset/open-space
Biodiversity	Bushbank Project Biodiversity Rank	https://discover.data.vic.gov.au/dataset/bushbank-project-biodiversity-rank1
	VPA Open Space data set	https://discover.data.vic.gov.au/dataset/open-space
	Vicmap Planning – Planning Scheme	https://discover.data.vic.gov.au/dataset/vicmap-planning-planning-scheme-zone-polygon
	Local government conservation reserves	Relevant Council open space strategies
Waterways	Port Phillip and Westernport Biolinks Mapping	https://portphillipwesternport.rcs.vic.gov.au/prospectus/bass-coast-biodiversity-biolinks

Spatial analysis to identify priority Mesh Blocks

Urban heat reduction priority areas

Morphum Environmental applied the prioritisation approach across metropolitan Melbourne. Each of the data sets was given a weighting based on thresholds defined by the Project Working Group. The weighted data sets for heat reduction were summed for each Mesh Block to derive the total urban cooling score. This score ranged from 0 (lowest priority) to 11 (highest priority). The number of Mesh Blocks (within the urban growth boundary) in each category of urban cooling score is presented below (Figure 2).

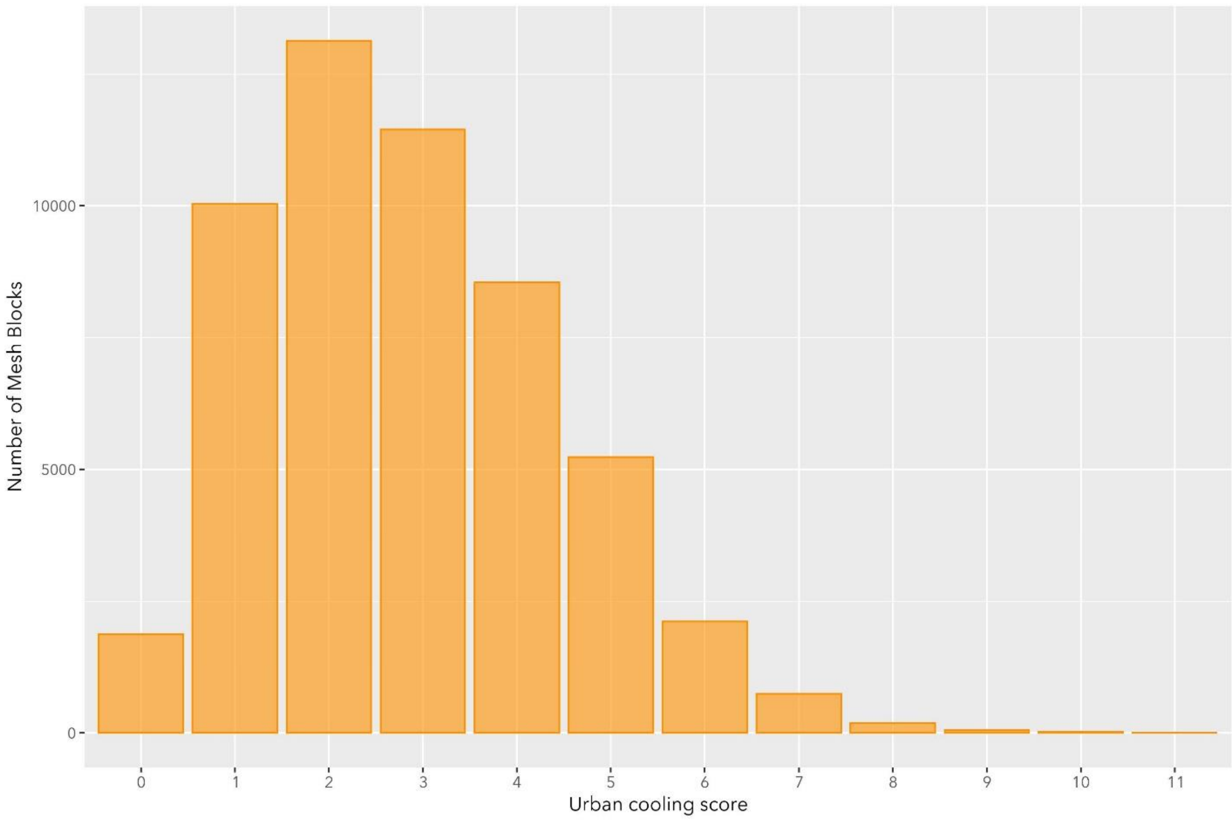


Figure 2: The distribution of Mesh Block total urban cooling scores (metropolitan Melbourne, within urban growth boundary)

After assessing this distribution, and considering the location and characteristics of the Mesh Blocks within each score category, 8,261 Mesh Blocks were selected as priorities for greening to reduce urban heat. This priority group comprised Mesh Blocks with a total urban cooling score between 5 and 11. Peri-urban Mesh Blocks categorised as 'primary production' and Mesh Blocks categorised as 'residential' over 1 km^2 in area (indicating large urban development either planned or under construction) were excluded from the analysis.

Biodiversity priority areas

Using a similar method to the heat reduction prioritisation, Morphum Environmental applied the biodiversity priority approach to Mesh Blocks across metropolitan Melbourne. The data sets in Table 2 had weightings applied and were summed within each Mesh Block to calculate the biodiversity score, which ranged from 0 (lowest priority) to 32 (highest priority). The number of Mesh Blocks (within the urban growth boundary) in each category of biodiversity score is presented below (Figure 3).

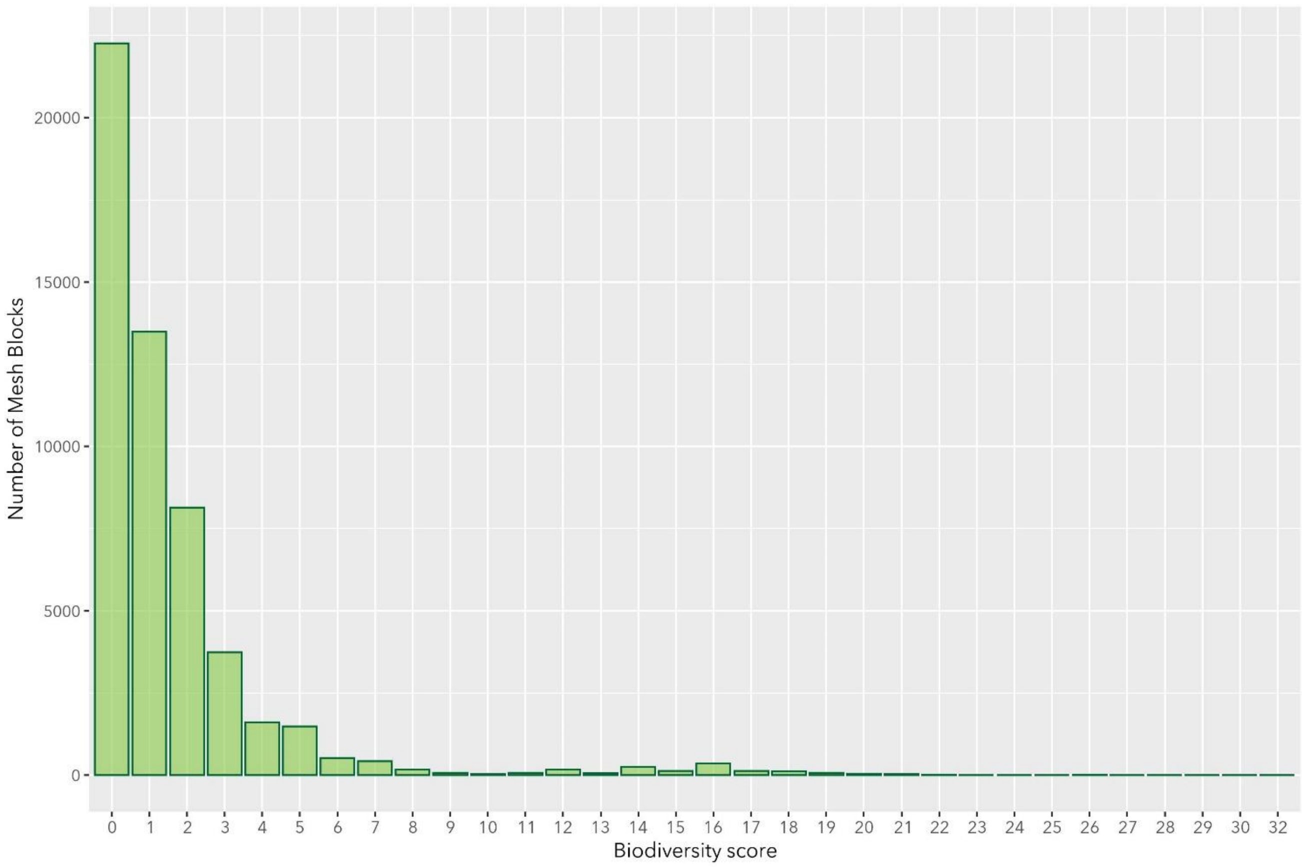


Figure 3: The distribution of Mesh Block total biodiversity scores (metropolitan Melbourne, within urban growth boundary)

As with the selection of heat reduction priority areas, the location and characteristics of Mesh Blocks were taken into consideration with overall distribution of scores when defining the priority areas for enhanced biodiversity. This group included Mesh Blocks with a biodiversity score between 4 and 32 (5,725 Mesh Blocks in total). Mesh Blocks with a score of three and below were not considered priority areas (for example, Mesh Blocks in this category and below encompass areas around freeways and major arterial roads, which were not considered to be a priority for greening for enhanced biodiversity).

The spatial distributions of priority Mesh Blocks for heat reduction and enhanced biodiversity are shown below (Figure 4 and Figure 5 respectively).

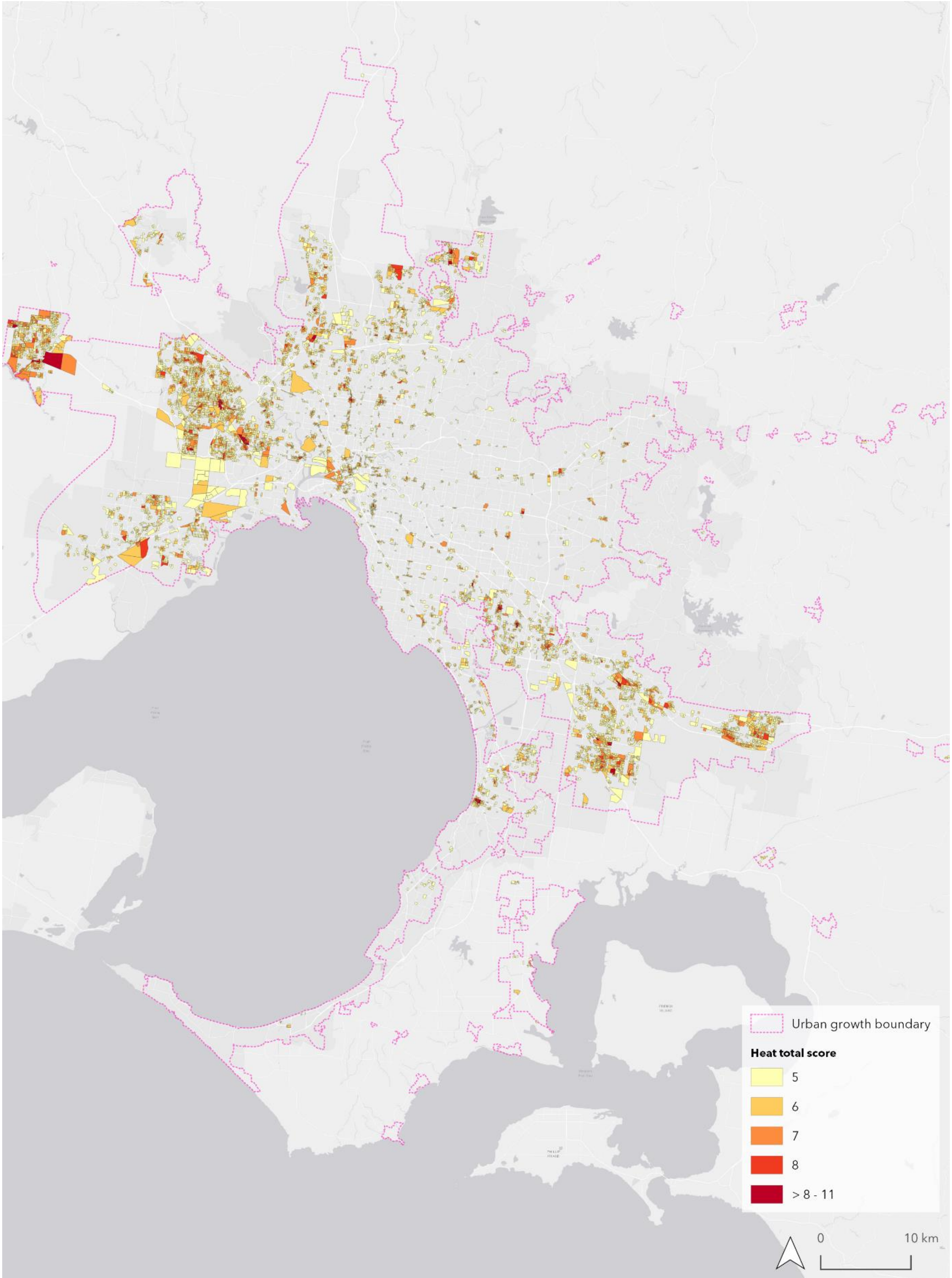


Figure 4: Location of priority Mesh Blocks for urban heat reduction

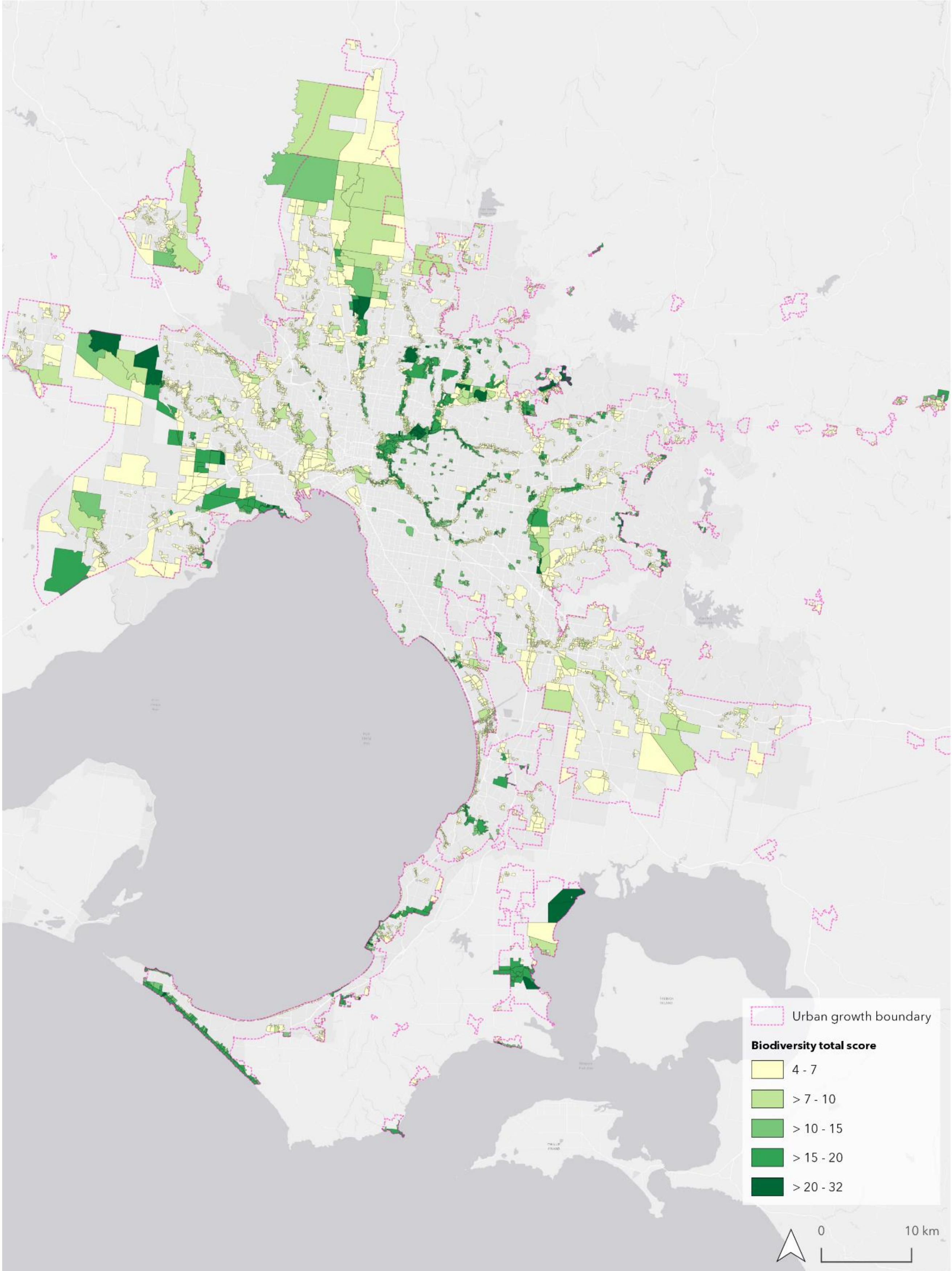


Figure 5: Location of priority Mesh Blocks for enhanced biodiversity

2.3 Analysing the cost of greening priority areas

Urban greening thresholds

Understanding the number of trees or plants required to reduce urban heat or enhance biodiversity in priority areas is critical to accurately estimating the costs of priority urban greening. To do this, a desired greening threshold is needed to set an ambitious but realistic upper limit of greening. Comparing the current level of greening at the Mesh Block scale to the relevant greening threshold allows the required number of trees or plants to be calculated.

The greening thresholds are expressed in terms of tree canopy cover for heat reduction priority areas and biodiversity site quality (related to vegetation cover and number of plants) for enhanced biodiversity priority areas. The method used to develop these thresholds is described below (and more detail is provided in Appendix B).

The scope of this project did not include modelling of the growth, decline and removal of existing trees or vegetation over time. For the purposes of the analysis it was assumed that ongoing investment in urban forest and vegetation management would be maintained at its current level, and the analysis considered the additional trees and vegetation needed in priority areas to reach the greening thresholds.

Thresholds for urban heat reduction priority areas

Tree canopy cover thresholds were set for individual Mesh Blocks based on their primary land use. The thresholds reflect the capacity of different land uses to accommodate trees in the public domain. This approach is aligned with work to set specific and achievable canopy targets in the City of Sydney (Julian, 2020). The 90th percentile of existing canopy cover (by Mesh Block land use, calculated using Vegetation Cover–Modified Mesh Block (2018)) was calculated and used as a threshold for canopy cover. To do this, the percentage canopy cover for every Mesh Block in each primary land use category was extracted from the spatial data and the 90th percentile canopy cover was calculated (Table 3). Selecting the 90th percentile as the threshold removed outliers that are unrepresentative of the level of greening that can realistically be achieved on the ground across all Mesh Blocks of each land use category.

In addition to overall canopy cover thresholds for Mesh Blocks, it was necessary to assess the capacity for the greening of road reserves and open spaces within the Mesh Blocks. For example, a road reserve in an industrial area is likely to have a lower capacity for canopy cover than a road reserve in a residential area due to the (typically) higher level of constraints in an industrial area. Similarly, a sports ground will typically have lower capacity for canopy cover than a neighbourhood park due to the requirement for a large area of the space to be unencumbered by trees to allow sporting activities to take place. The 90th percentile of existing canopy cover within road reserves (by Mesh Block land use) and open space (by VPA open space category) was calculated and used as the greening threshold for road reserves (by Mesh Block land use) or open space type (Table 3 and Table 4).

Table 3. 90th percentile tree canopy cover for selected land use categories for entire Mesh Blocks and road reserves.
Data: Vegetation Cover–Modified Mesh Block (2018)

Mesh Block land use	Mesh Block canopy cover 90th percentile	Road reserve canopy cover 90th percentile
Residential	26%	30%
Commercial	16%	19%
Industrial	12%	15%
Education	27%	31%
Parkland	40%	34%

Table 4. 90th percentile tree canopy cover for selected open space types
Data: Vicmap Vegetation (Tree Point and Tree Extent)

Open space type	Canopy cover 90th percentile
Conservation reserves	100%
Government schools	38%
Natural/semi-natural	98%
Parks and gardens	72%
Public housing reserves	45%

Thresholds for enhanced biodiversity priority areas

Setting thresholds for high priority areas for biodiversity planting was based on a site quality approach developed by DSE (2006) and DELWP (2015). The intent of these standards is to guide the planting of locally indigenous species and to achieve 10 year plant density targets based on the relevant Ecological Vegetation Class benchmark (see this website for more details). The standards provide a target number of plants per hectare for overstory and understory trees, medium and small shrubs and large tufted grasses and grass-like plants.

Three levels of site quality were used to set thresholds to allow the number of plants to maintain or move the site quality to 'high' to be estimated (Table 5). Generally, plant numbers per hectare required for supplementary planting should be less than the number of plants required for revegetation purposes where a site has been fully cleared so the plant numbers required for each category reduced with increasing site quality. High site quality was used as the threshold for biodiversity plantings.

Table 5. Biodiversity site quality categories and plants/hectare required to meet threshold quality

Site quality	Description	Plant numbers proposed per hectare	Rationale for estimate of plants / hectare
Low	Sites that have very limited or no remnant vegetation, likely to have been previously cleared for agriculture or other use	20,000-40,000 across all categories	Extensive re-set required to re-establish vegetation that contributes to biodiversity value
Medium	Sites may have scattered remnant vegetation in peri-urban or rural areas, or former agricultural land with some patches of remnant vegetation	2,500-10,000 across all categories	Improvement can be achieved by partial rehabilitation of the site where some strata are lost due to previous disturbance
High	Sites dominated by remnant vegetation (may comprise entirely of native vegetation), requiring minimal revegetation effort	0 – 10,000 across all categories	Site may be largely intact, and no benefit realised from additional vegetation installed

How many trees or plants are needed?

Spatial analysis was undertaken to quantify the current level of greening and calculate the number of trees or plants needed to meet the greening thresholds for every priority Mesh Block.

Urban heat reduction priority areas

Streets and open spaces in each of the 8,261 priority Mesh Blocks were analysed to estimate the number of trees needed to meet the greening threshold in priority areas for heat reduction, as described below.

The number of trees required to meet the threshold in road reserves was estimated for each priority Mesh Block by extracting:

- The current canopy cover in road reserves within the Mesh Block
- The number of trees in road reserves within the Mesh Block
- The length of road reserve within the Mesh Block available for planting

The current canopy cover in road reserves was compared to the threshold for road reserves in Mesh Blocks with the relevant land use (e.g., 30% canopy cover for a residential Mesh Block, as described above). The total number of trees required to increase canopy cover to the threshold was calculated. If this number was greater than the length of road reserve in the Mesh Block available for planting divided by a standard tree spacing, this maximum number of trees was taken to the next stage of the analysis instead. Several assumptions were made in the street tree analysis:

- Street tree spacing of 10 m used when calculating the capacity of road reserves for planting
- Canopy diameter of new trees of 8 m[1]
- Median verges were not included in the length of street available for planting
- Streets with a speed limit of greater than 60 km/h excluded

[1] Assumed canopy diameter of new trees based on technical analysis conducted from the Metro Tunnel Tree Canopy Replacement Program.

The outputs from this analysis (for each priority Mesh Block for heat reduction) were:

- Length of street suitable for street tree planting—derived from a data set created by Hurley et al. (2019) and Hurley et al (2020) that partitioned roads from other land uses using Modified Mesh Blocks
- Area of tree canopy within road reserves
- Percentage of road reserve covered by tree canopy
- Number of additional trees needed to bring canopy cover in road reserves in each Mesh Block up to the relevant threshold

A similar analysis was carried out to calculate the number of trees needed to reach the relevant threshold for open spaces in each priority Mesh Block. The assumptions in this analysis were:

- Public open space with open access and public open space with limited access (such as cemeteries and tertiary institutions) were included in the assessment
- Golf courses, racecourses and privately-owned open space were excluded
- 8 m canopy diameter for new trees

Upon completion of this analysis, the following outputs were generated:

- Area within each Mesh Block of each open space type
- Existing canopy cover of each open space type per Mesh Block
- Number of additional trees needed to bring open space type present within each Mesh Block up to the threshold for that open space type

Combining the outputs from the street and open space analysis provided the total number of trees needed to bring each priority Mesh Block for heat reduction to the relevant threshold.

Biodiversity priority areas

A different approach was used to estimate the number of plants needed to reach the greening thresholds in the 5,725 Mesh Blocks identified as priority areas for enhanced biodiversity. Each Mesh Block was analysed in combination with the VPA Open Space data set to identify areas that could be realistically set aside for planting vegetation for enhanced biodiversity. The VPA Open Space data set was filtered for open spaces with the open space category 'natural and semi-natural open space' or 'conservation reserve'. 'Parkland' open spaces were excluded, as the primary purpose of these spaces is recreational activities such as mountain biking and dog walking that are not compatible with a primary biodiversity or conservation function.

The total area suitable for biodiversity planting within biodiversity priority Mesh Blocks comprised the sum of the area of natural/semi-natural and conservation VPA open space typologies. This figure was used as a core input for the biodiversity cost analysis.

An important limitation of the estimate of plants and costs for enhanced biodiversity is a lack of reliable data on the current condition of biodiversity areas. As described above, current site quality is used in this study to estimate the number of plants per hectare needed to bring site quality to the greening threshold of high quality. In conjunction with the Project Working Group an assumption was made of the proportion of the total area available for biodiversity planting in different categories (Table 6).

Table 6. Assumed proportion of area available for biodiversity planting in site quality classes

Site quality	Percentage of total area available for biodiversity planting
High	5%
Medium	65%
Low	25%

More details on the methods and results of the analysis used to estimate the number of trees and plants for priority greening are provided in Appendix B.

Cost analysis

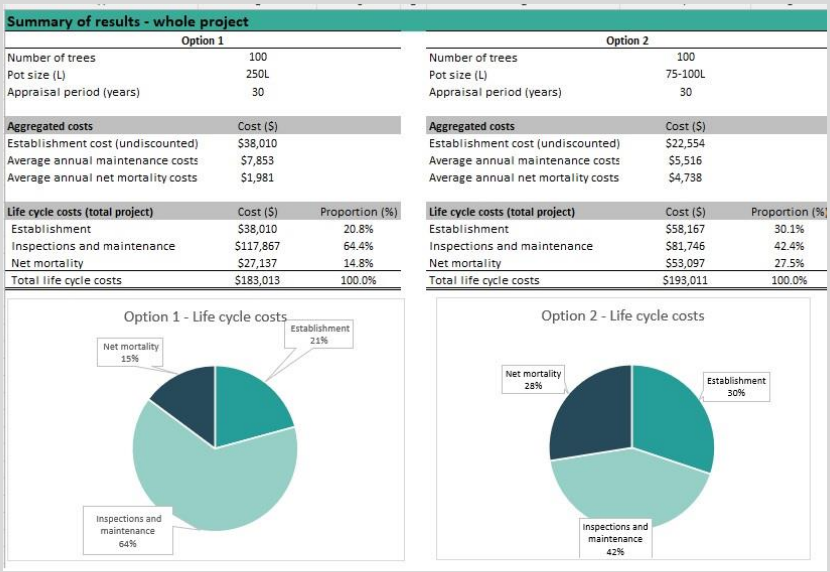
The total cost of achieving greening thresholds is the sum of the cost for tree planting in priority heat reduction areas and vegetation planting in priority biodiversity enhancement areas. Both tree and vegetation planting costs were estimated using Horticulture Innovation Australia's Tree Costing Tool, which calculates the lifecycle costs of urban tree and vegetation projects (see Box 2 for more detail on the Tree Costing Tool). The process of estimating costs to achieve the greening thresholds has three broad steps:

1. Identify the number of trees and plants needed to achieve greening thresholds in priority areas (as described in Section 2.3).
2. Estimate the lifecycle cost per tree and cost per area to achieve the thresholds.
3. Multiply the number of trees and plants by their respective unit costs to calculate total costs.

Box 2. The Tree Costing Tool

The Tree Costing Tool was developed by NCE and Mosaic insights for Horticulture Innovation Australia. This comprehensive and peer-reviewed model estimates the full lifecycle cost of urban vegetation establishment, including all relevant capital costs (tree and installation, related infrastructure, traffic management etc.), the costs/risks of mortality, operational and maintenance costs and any long-term replacement costs. This model was specifically designed and tested by industry and local government experts to estimate the cost components of major urban tree business cases. It provides rigorous estimates of the establishment and ongoing costs of vegetation establishment and allows for the analysis of operational risks such as tree mortality to be incorporated into the analysis to better understand the true trade-offs between different management regimes.

A screenshot of an example of the outputs from the Tree Costing Tool is shown below.


Summary of results - whole project

	Option 1			Option 2	
Number of trees	100		Number of trees	100	
Pot size (L)	250L		Pot size (L)	75-100L	
Appraisal period (years)	30		Appraisal period (years)	30	
Aggregated costs	Cost ($)		**Aggregated costs**	Cost ($)	
Establishment cost (undiscounted)	$38,010		Establishment cost (undiscounted)	$22,554	
Average annual maintenance costs	$7,853		Average annual maintenance costs	$5,516	
Average annual net mortality costs	$1,981		Average annual net mortality costs	$4,738	
Life cycle costs (total project)	Cost ($)	Proportion (%)	**Life cycle costs (total project)**	Cost ($)	Proportion (%)
Establishment	$38,010	20.8%	Establishment	$58,167	30.1%
Inspections and maintenance	$117,867	64.4%	Inspections and maintenance	$81,746	42.4%
Net mortality	$27,137	14.8%	Net mortality	$53,097	27.5%
Total life cycle costs	$183,013	100.0%	Total life cycle costs	$193,011	100.0%

2.4 Estimating the value of the benefits of greening priority areas

Urban greening provides a range of environmental, social and economic benefits. In this section the benefits likely to flow from successful greening of priorities areas are discussed. Two categories of benefits were considered: quantified benefits (i.e., benefits that can be assigned an estimated dollar value) and unquantified benefits (i.e., benefits that have a strong evidence base but cannot be confidently assigned a monetary value in the context of this study).

Introduction to the ecosystem services framework

Ecosystem services are defined as the goods and services derived by humans from the environment. According to the Common International Classification of Ecosystem Services (CICES) presented by Haines-Young and Potschin (2018) ecosystem services are typically categorised into four types:

Social and cultural services: service directly experienced by humans (e.g., recreation, tourism, aesthetic appreciation, and spiritual experience).

Provisioning services: services that describe the material or energy outputs from ecosystems (e.g., temperature reduction).

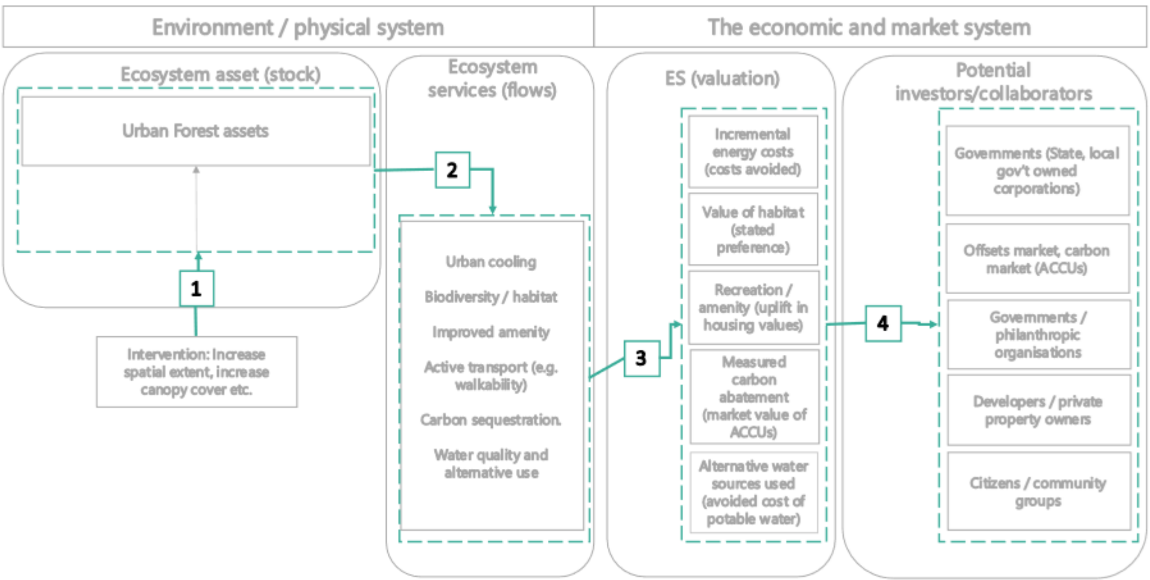
Regulating services: the services that ecosystems provide by acting as regulators (e.g., carbon sequestration).

There is also a fourth, intermediate, category for ecosystem services that can capture values that could be excluded from the typical ecosystem service framework:

Supporting services: services that underpin other ecosystem services categories (e.g., habitats or species and maintenance of genetic diversity).

In applying the ecosystems services framework, a structured approach and consistent logic was used to link biophysical information to economic information and modelling (prioritisation and cost-benefit analysis) as shown below (Figure 6).

Figure 6: Process of linking biophysical systems to economic systems for greening projects



The benefits described in this section draw on a range of valuation methodologies, particularly for non-market values. While primary research would yield the most accurate reflection of benefit values, there was a trade-off and limitation in terms of time and data availability. Thus, in this assessment, a *benefit transfer* approach was adopted across all benefit values. This approach involved applying estimates from previous relevant studies gathered from review of the peer reviewed and grey literature. Examples of different valuation methods are provided in the table below.

Method	Based on …	Useful for …
Market-based techniques		
Replacement cost	Costs of replacing a service	Reduced future costs of dredging sediments
Avoided cost	Avoiding costs to business or government service delivery	Avoided wastewater treatment plant augmentation to meet regulated nutrient thresholds
Non-market-based techniques		
Hedonic pricing	Values of goods bundled with market traded goods (e.g., aesthetic amenity/view which is accessed through buying a house in a particular neighbourhood)	The recreational value of improvements in water quality and recreational uses of receiving environments (e.g., primary, secondary, tertiary use)
Travel cost	Costs incurred in visiting a site	Valuing tourism, recreation, or cultural use of a site
Stated preference techniques	Surveys and community willingness to pay to protect an asset	The value of the existence and improvement of biodiversity and ecosystem functions
Benefit transfer	Studies undertaken in similar locations. The original studies could have involved any of the techniques outlined in this table	Situations where budgets are constrained and primary research into non-market values are not possible

The benefit values were quantified using a discounted cashflow approach over a 30-year appraisal period. Some benefits were estimated as a once-off benefit which was only incurred in Year 1 and other benefits were annualised across the 30 years. Future values were discounted to present value terms using a discounting cash flow approach with a 7%, with a suggested range (for sensitivity analysis) of 3–10% (Infrastructure Australia, 2022).

Quantified benefits

The quantified benefits in this project are summarised below.

Carbon sequestration – Trees remove carbon dioxide from the atmosphere through their biophysical structure and growth. To estimate the volume of carbon sequestered by a mature tree, we take estimates provided by i-Tree Eco, a tree assessment model developed by the United States Department of Agriculture, which has been calibrated for the Australian context. Australian Carbon Credit Unit Prices were used to quantify the value of the carbon sequestered.

Avoided expenditure on space cooling – The increase in tree canopy cover in residential neighbourhoods provide additional shade to buildings during hot weather, reducing the need for and household expenditure on electricity for cooling. To quantify the scale of this benefit, we estimated the potential reduction in household energy use based on the proximity to trees.

Avoided productivity losses – Climate change is expected to increase the frequency and severity of hot days in the future. This will result in a loss in labour productivity as conditions become too hot for workers in sectors that require them to be outdoors such as the construction sector. In Victoria, a 35C temperature is the 'tools down' temperature threshold, and work stops after this point for the safety and wellbeing of outdoors workers. An increase in canopy cover provides additional cooling and lowers temperatures experienced by outdoors workers, enabling them to remain productive for longer. To quantify this benefit, we estimated the potential reduction in temperatures associated with increasing tree canopy cover, and the avoided number of work absentees from high temperatures.

Reduced management costs from stormwater runoff – Stormwater runoff contains a range of different pollutants and negatively impacts water quality and health of ecosystems. The economic value of this benefit is estimated in terms of avoided management costs of stormwater impacts for trees designed with water sensitive urban design (WSUD) infrastructure. Urban trees remove pollutants from stormwater runoff by storing water in the soil, evaporation and transpiration (Denman et al., 2011). General assumptions were made around avoided runoff volume captured per mature tree using i-Tree Eco and the approach described in Marsden Jacobs Associates (2022) was followed.

Amenity value of trees – There is evidence in the literature to suggest that there will be an economic uplift for properties situated in a neighbourhood with desirable green infrastructure, reflecting a bundle of corresponding benefits (e.g., increased recreation, amenity, urban cooling, etc). These benefits are considered in Victorian Government strategies and plans relating to urban greening. For example, Open Space for Everyone (DELWP, 2021), the Victorian Government open space strategy for metropolitan Melbourne, cited a study that estimated the amenity value for some 12,000 residents immediately adjacent to metropolitan parks in Melbourne to be $21–28 million a year.

In terms of quantified benefits from urban greening, research by Plant, Rambaldi, and Sipe (2017) found that a 1% increase in canopy cover is associated with a 0.10% increase in property prices. They estimated this value using a hedonic pricing model, a non-market valuation technique to tease out homebuyer's willingness to pay for an incremental increase in canopy cover, while considering the influence and desirability of other housing and neighbourhood characteristics e.g., property size, garage space, number of bedrooms, availability of public transport, school quality etc. It should also be noted that this reference study also accounted for property values over a period of two years, capturing market conditions. Thus, the resulting estimates isolate the specific willingness to pay value for increased canopy cover. However, the authors also noted that there is a limit to this benefit for trees on private land at 20% canopy cover of private trees on the house site. This could potentially be driven by perceived fire risks, obstruction of views, and increased maintenance costs.

In this study, we applied the benefit rate to households close to desired levels tree canopy cover estimated by Plant, Rambaldi, and Sipe (2017).

While this increase in property value may reflect homeowners' desire to live in a greener neighbourhood, it does not consider individual reasons such as improved visual amenity or the effects that an increase in canopy cover or access to green space can have on improving mental wellbeing and health. Thus, the value for each individual benefit is not explored in this report because of the likelihood that these benefits are already captured in the hedonic pricing estimate.

More detail on the methods used to quantify the value of these benefits is provided in Appendix C.

Unquantified benefits

There are several benefits from greening for which there is strong evidence in the literature but were not quantified in this project. One of the main challenges encountered in this study was the limited information available at the metropolitan-scale to enable us to quantify the value of enhanced biodiversity. While there are studies that examine how urban greening may provide other benefits such as improvements in mental health and wellbeing, there is insufficient data in the scope of this study for us to estimate the monetary value of these benefits with confidence. This is explained further below.

Enhanced biodiversity – Improvements to biodiversity from investment in targeted planting will lead to increases in several benefit values under the lens of the ecosystem services framework. This includes the benefits canvassed above—such as carbon sequestration, amenity, and wellbeing benefits from proximity to green spaces—but also the existence and intermediary benefits that may pertain to specific flora and fauna.

At a high level, estimating the value of these benefits requires establishing the biophysical links between ecosystem condition and downstream services, and the anthropogenic values associated with these services. For the purposes of this project, there was insufficient data to further explore and quantify the benefits from biodiversity (as further elaborated below).

Mental wellbeing from proximity and exposure to vegetation – There is strong evidence in the literature on the mental health benefits, such as stress reduction, attributable to proximity or exposure to green infrastructure in an urban setting (albeit in smaller scale studies). A key challenge associated with quantifying this benefit is the lack of research identifying the link to anthropogenic values that reflect the benefit of improved biodiversity on mental health, particularly for the scale of urban greening considered in this project. Further, a systematic review of 24 studies conducted by Marselle et al (2019) found that 17 of these studies report non-significant effects on mental health. Some of the amenity benefits derived from urban greening may already be included in the estimation of the value for amenity and urban cooling, and so further incorporating this class of benefits may lead to double counting.

Noise reduction – Although there is some evidence to suggest that roadside vegetation of sufficient density can dampen traffic noise, there is insufficient information to quantify this benefit in economic terms. Further, there is a risk of double counting as noise reduction may already be captured in the estimate for the amenity value of trees.

Limitations

The overarching goal in this study is to estimate the net economic benefit (or disbenefit) of investment in greening to reduce urban heat and enhance biodiversity in priority areas of metropolitan Melbourne. In doing so, broad assumptions were made in the quantification of these estimates. Some of the key limitations identified in the study—and suggestions on how to address them in future work—are discussed in this section.

Improving biophysical relationships between increased greening and heat/water processes

Robust economic assessments should be built on robust biophysical science. The analysis undertaken in this study is based on the best available data. However, there are areas where an improved, quantitative understanding of the causal relationships between urban greening, the specific benefits from greening and the unit values of those benefits in an Australian or Melbourne metropolitan context would reduce the uncertainty around the results. Some of the key areas for improved understanding are discussed here.

1. The relationships between increased greening and the cooling effect they provide at the metropolitan-scale would allow the value of specific urban climate-related benefits to be more accurately estimated. The analysis in this study relies on high-level assumptions regarding the degree of canopy cover and extent of cooling provided, which means it is challenging to capture the benefits that have been described qualitatively above. Specific areas for improved knowledge include:
   - A better understanding of the incremental reduction in peak temperatures from increased canopy cover rates.
   - An improved understanding of relationship between reductions in temperature and household energy consumption.

2. Improving the quantitative understanding of the relationship between increased canopy cover and stormwater management objectives, in particular:
    - An improved understanding of the relationship between canopy cover and reduced flow volumes to downstream waterways would allow improved estimates of the avoided costs from reduced damage to built infrastructure by increased waterway erosion from urban flows.
    - A better understanding of the relationship between canopy cover and reduced pollutant loads from urban runoff (particularly nitrogen).

There is greatest uncertainty in these relationships where urban trees are not part of WSUD infrastructure (such as biofiltration systems).

It is recommended that these limitations are addressed through a well-designed research program in the short- to medium-term. Improving the understanding of these causal relationships will provide benefits to policy makers, planners, regulators and investors beyond metropolitan Melbourne.

Estimating the benefits of mental wellbeing from proximity and exposure to vegetation

The research identified difficulties in estimating the benefits for improved mental wellbeing from exposure to vegetation, as the scale of this study makes it challenging to estimate the value of this benefit with confidence. Therefore, these benefits were not included in the quantitative estimates of benefits.

Given the clear evidence for this important benefit in the literature (e.g., Wolf et al 2020), we recommend a pragmatic approach is taken to future research that focusses on case studies of representative sites. This approach would allow more detailed information on factors such as provision and nature of open spaces in the study area and the demographics and health profile of prospective beneficiaries.

Estimating the benefits from habitat improvement

The ecosystem services attributable to urban habitat are broadly understood, but issues such as minimum viable threshold areas are less-well understood, particularly information specific to metropolitan Melbourne.

We believe that future research on specific case study sites where the vegetation species can be identified can inform a more detailed analysis of the economic costs and benefits that flow from improved habitat.

Limitations of the benefit transfer approach

This study does not include any primary research on economic values. Rather, unit values of economic benefits are transferred (inferred) from studies undertaken elsewhere. During this process, some of the studies that we have relied on were developed based on data on different geographical and temporal contexts, creating uncertainty. While this uncertainty has been reflected in the estimates through the sensitivity analysis conducted and the ranges of estimates provided, the findings should still be treated with caution.

2.5 Cost-benefit analysis

Overview of the cost-benefit analysis approach

The cost-benefit analysis (CBA) applied in this assessment estimates the net benefit of priority urban greening across metropolitan Melbourne. The assessment draws on a traditional CBA approach supplemented by an ecosystem services framework to identify and value costs and benefits associated with greening (Figure 7). An ecosystem services approach is necessary as it allows the valuation of the non-market benefits that flow from greening.

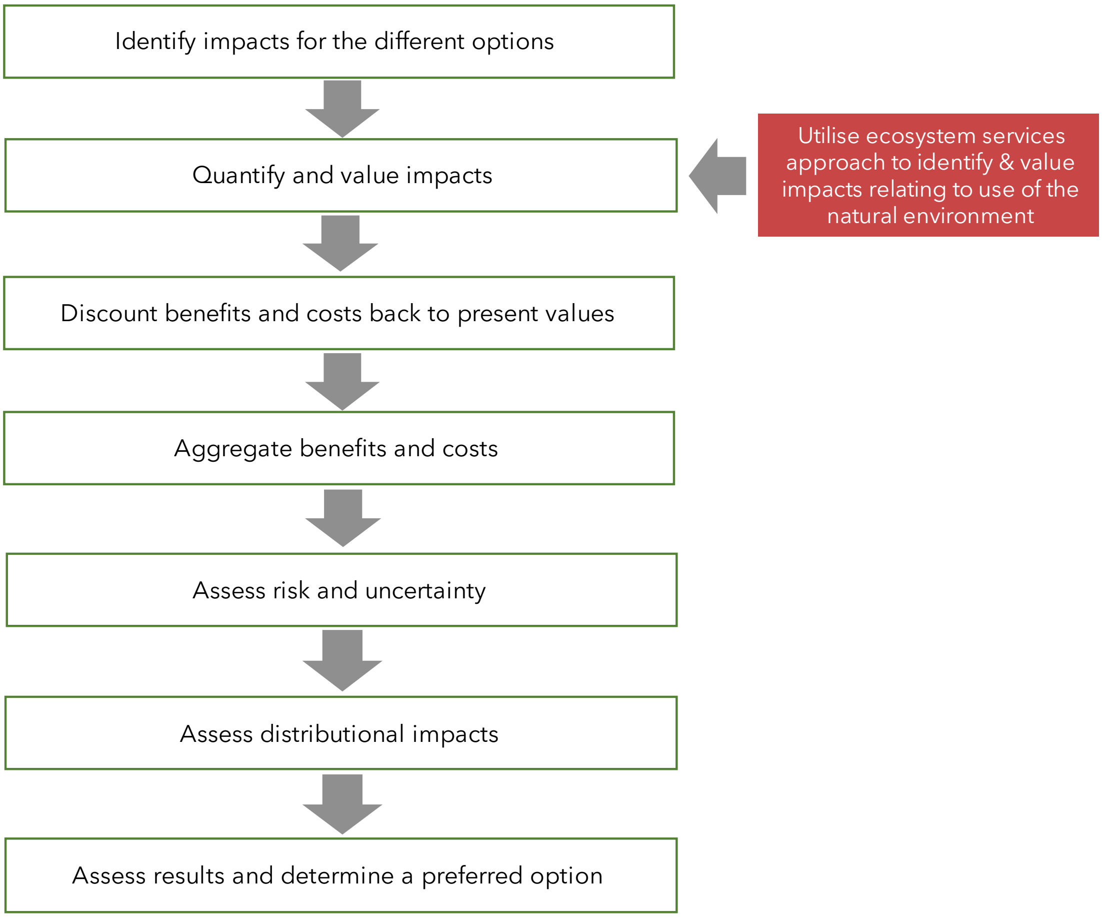


Figure 7: Steps in a cost-benefit analysis

The combination of an ecosystem services framework and various environmental economic valuation approaches allows the life-cycle benefits from priority greening to be identified, scoped and valued. In conjunction with the estimates of the lifecycle costs, this provides the information basis for the cost-benefit analysis and economic prioritisation, as illustrated below (Figure 8).

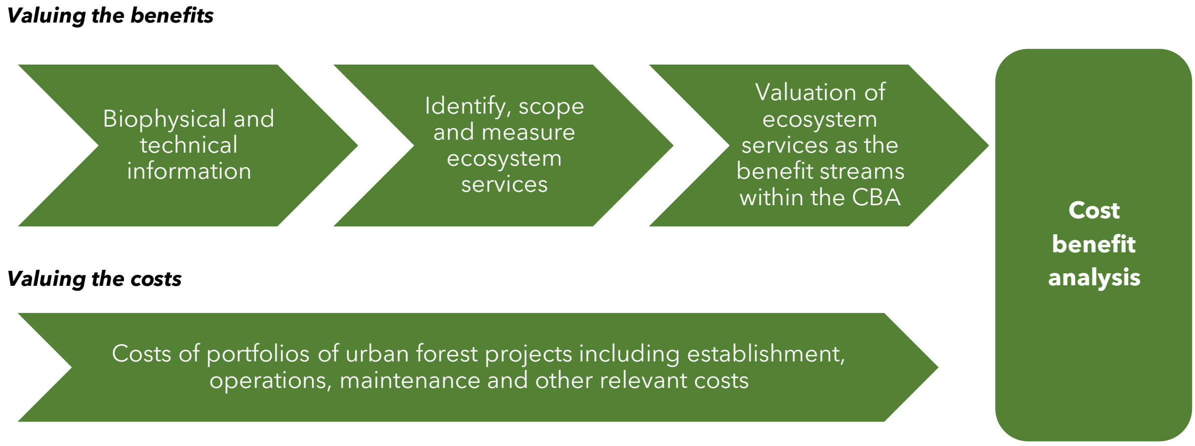


Figure 8: Overview of the economic modelling approach

The benefit values were quantified using a discounted cashflow approach. This involved determining the benefits for each year in the appraisal period—which was assumed as 30 years. Future values were discounted to present value terms using an established discount rate.

Risk and uncertainty

The key approach to addressing risk and uncertainty in the analysis was the use of Monte Carlo simulations (see Appendix D for more details). This approach, unlike scenario-based methods, allows for multiple parameters to be captured concurrently within the sensitivity analysis. This provides useful insight to future research, data gathering, data quality and ongoing targeting for monitoring and evaluation of project outcomes, and critically, information on what issues to focus on when attempting to improve estimates in the future.

3 Here's what we found

Following the discussion of the approach in Section 2, in this section we discuss the overall results from the modelling exercise and highlight key findings from our analysis. We begin by presenting the headline figures and aggregate values, and then discuss the results on a more disaggregated level.

3.1 Headline figures

The tables below present the results of the CBA and show the mostly likely result with the 10th and 90th percentile (P10 and P90) estimates in parenthesis. The P10 and P90 values represent the values above which 10% of the results and below which 90% of the results fall. By excluding the highest and lowest 10% of values the robustness of the estimates is increased. The P10 and P90 values can be considered conservative (low) and high estimates respectively.

A benefit-cost ratio greater than 1 indicates that the project is expected to return a positive net present value, and a BCR below 1 indicates that the project is unable to deliver positive returns and is not economically viable. The estimated aggregate costs, benefits, and BCR are presented below (Table 7). The headline figures for the cost-benefit analysis are:

- Total costs are estimated at $3.1 B. Of this, the establishment costs are $2.0 B of the total costs
- Total benefits are estimated at $12.6 B
- The BCR is estimated at 4.0. This means that for every $1 of investment, there will be a return of $4.

Table 7. Aggregate results from cost-benefit analysis

	Value (P10 - P90)
Total costs for achieving greening thresholds (priority urban heat reduction and biodiversity)	$3.11 B (2.59 – 3.86)
Total benefits	$12.56 B (6.66 – 20.69)
Benefit-cost ratio	**4.0 (2.2 – 6.7)**

The distribution of results from the sensitivity analysis of the BCR is illustrated below (Figure 9). The results show 90% of the results are within the range of 2.2 – 6.7, which indicates that even the conservative estimate of the benefit vs cost comparison produces a positive result.

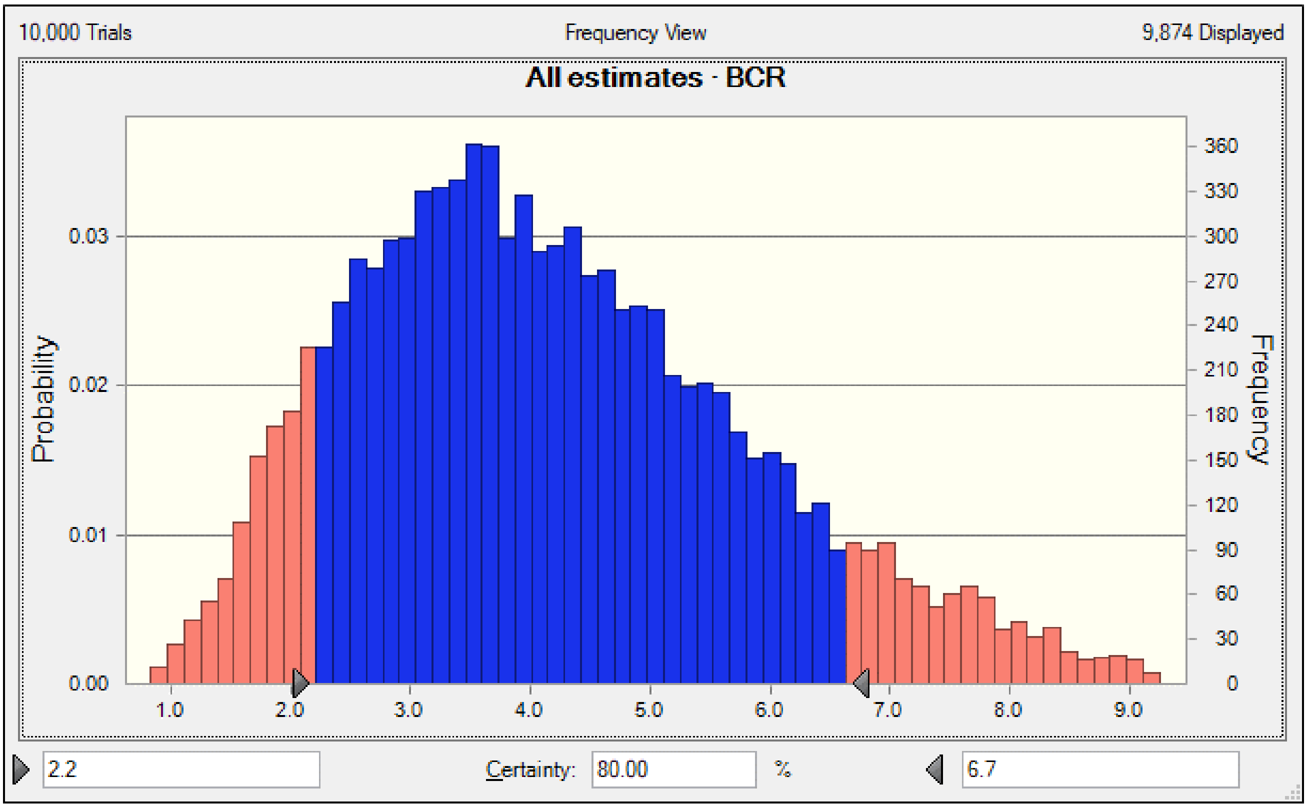
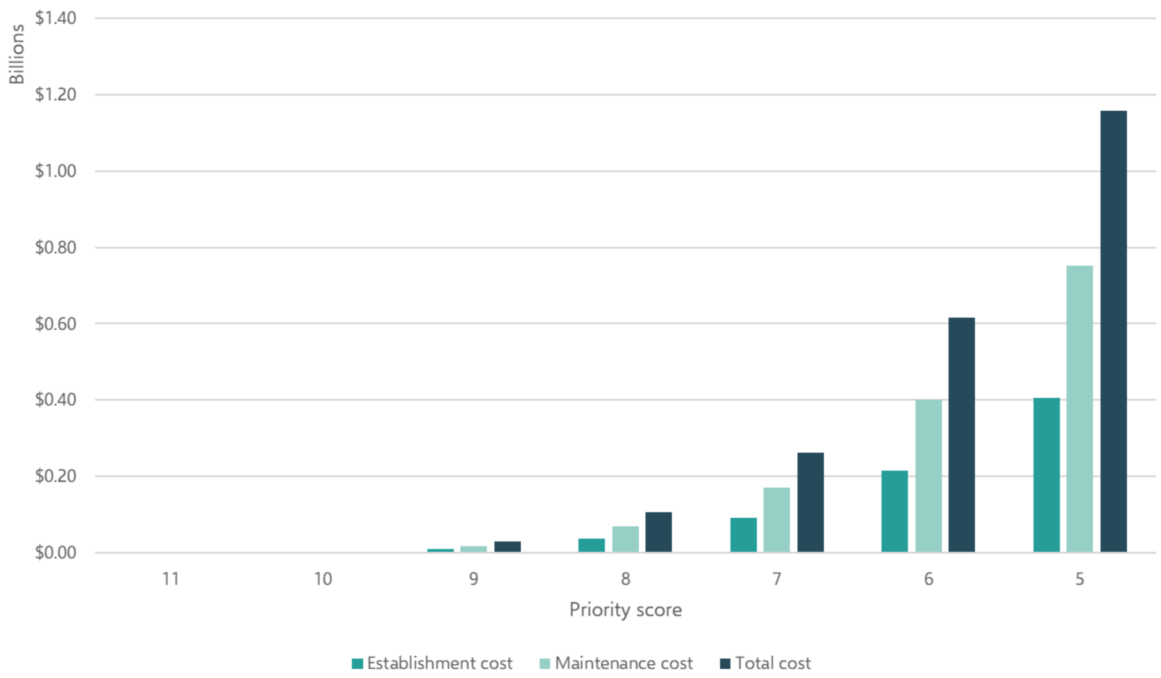


Figure 9: Benefit-cost ratio estimates

3.2 Costs of urban greening

The total costs for greening priority areas are estimated at $3.1 B. 70% of this cost ($2.2 B) is to plant 590,000 trees in priority heat reduction areas and 30% is to revegetate 13,900 hectares in priority areas for enhanced biodiversity.

For both priority categories, the total lifecycle costs associated with reaching the greening threshold for all Mesh Blocks in each priority score category increases as the priority score decreases, indicating that the costs for planting increases in lower priority areas. The respective costs are presented below (Figure 10) for achieving the desired greening threshold in for heat reduction and enhanced biodiversity for all Mesh Blocks in each priority score category.



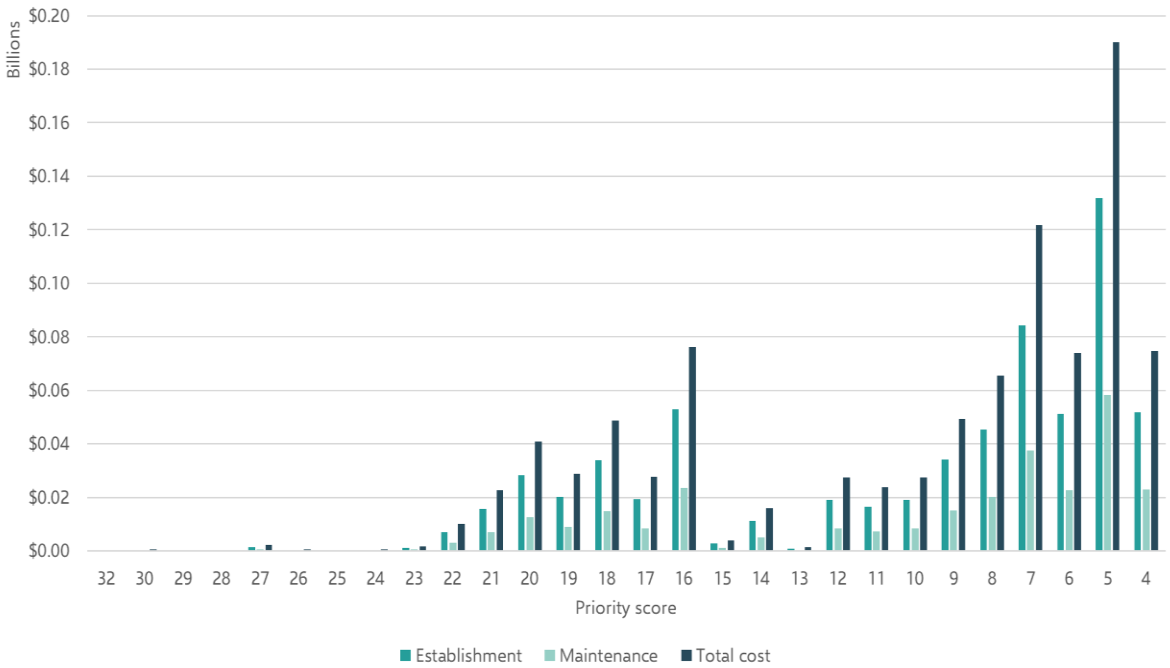


Figure 10: Costs for achieving greening thresholds in priority areas for heat reduction (top) and enhanced biodiversity (bottom).
Each bar shows the cost for reaching the greening threshold for all Mesh Blocks in each priority score category.

Establishment and maintenance costs for greening the highest priority areas for heat reduction and enhanced biodiversity are presented below (Table 8 and Table 9).

Table 8. Establishment and maintenance costs for priority heat reduction Mesh Blocks with the highest priority scores

Heat priority score	Establishment	Maintenance
11	$46,039	$85,371
10	$1,231,316	$2,279,592
9	$10,524,158	$19,482,146
8	$37,639,530	$69,678,647

Table 9. Establishment and maintenance costs for priority enhanced biodiversity Mesh Blocks with the highest priority scores

Biodiversity priority score	Establishment	Maintenance
32	$51,187	$22,662
30	$312,272	$138,252
29	$127,223	$56,325
28	$28,818	$12,758
27	$1,456,216	$644,710
26	$390,849	$173,041
25	$96,570	$42,755
24	$288,863	$127,889
23	$1,122,531	$496,978
22	$7,045,245	$3,119,141
21	$15,688,373	$6,945,713
20	$28,327,495	$12,541,432

The distribution of costs across the different land use for the two priority categories is illustrated below (Figure 11). Across both priority categories, planting in residential and parklands makes up most of the total expenditure.

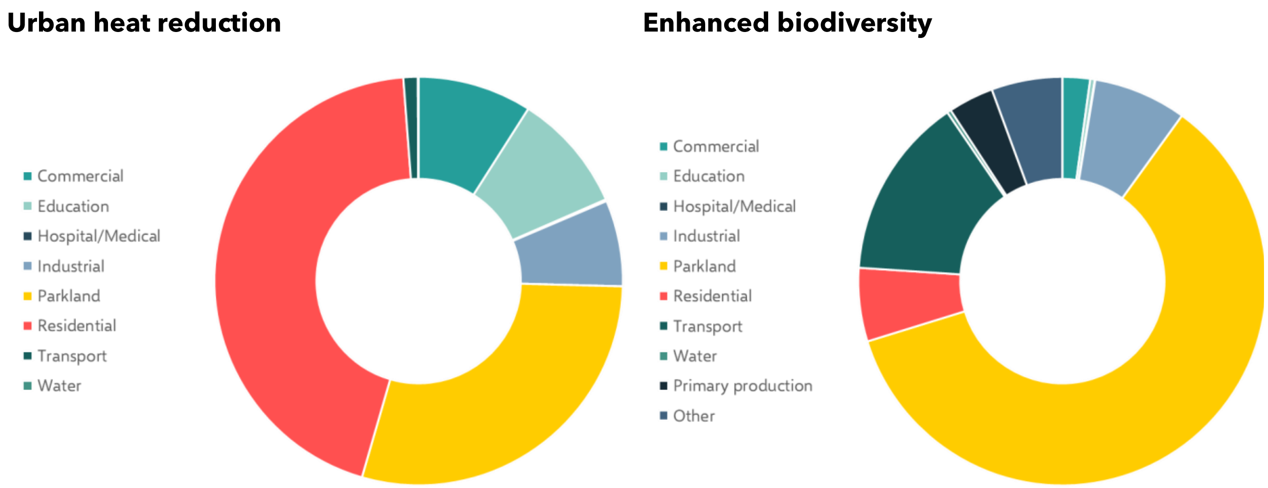


Figure 11: Distribution of costs across land use categories for priority urban heat reduction and biodiversity planting

3.3 Economic benefits of urban greening

The estimated monetary values flowing from greening priority areas are presented below (Table 10).

Table 10. Estimated economic values of benefits

Benefit		Value (P10 – P90)
Amenity value of trees		$11,813.4M (6,166.7 – 19,413.6)
Carbon sequestration		$1.20M (0.82 – 1.70)
Avoided expenditure on space cooling		$33.47M (9.00 – 77.32)
Avoided productivity losses		$751.9M (468.3 – 1,158.1)
Avoided management costs from handling stormwater runoff		$26.92M (18.26 – 38.09)
	Total	$12,626.8M (6,663.0 – 20,688.8)

To maximise the effectiveness of investment, initial tranches should focus on higher priority areas, as the resulting benefits are likely to be higher than subsequent tranches of investment in lower priority areas.

Determining the value of actual benefits from each tranche of investment will require additional data and analysis to determine the biophysical links of greening each priority Mesh Block and respective benefit categories. Regardless, the total value of benefits across all tranches will likely fall within the range of benefit values determined in this analysis.

4 Conclusions and recommendations

As part of the *priority urban greening initiative* nearly 14,000 Mesh Blocks across metropolitan Melbourne were identified as priorities for increased urban greening to reduce urban heat and enhanced biodiversity. A cost-benefit analysis of greening the priority areas was undertaken combining detailed spatial analysis, the latest information on the lifecycle costs of greening, and peer-reviewed research into the economic value of greening.

4.1 Conclusions

- For every $1 invested in urban vegetation, the return to the community, business and governments across metropolitan Melbourne is around $4 – with a range between a return of $2.16 and $6.70 for every $1 invested. Clearly the evidence available suggests that the investment is likely to 'stack up' and should be considered further.
- The lifecycle costs of planting 590,000 trees to reduce urban heat and 13,900 hectares of vegetation for improved biodiversity where we need them most are significant over the next thirty years. In today's dollars (what the economists call present values), the costs of reducing heat in high priority areas is estimated at $2.2 billion (range of 1.72 to 2.97). Over the same period, the costs of enhancing and protecting our biodiversity spaces are estimated at $0.9 billion (range of 0.87 to 1.00).
- The unit cost during the establishment phase can be around $1,113 per street tree. And ongoing costs over the next 30 years (pruning, watering, etc.) will be around $1,485 per tree. The ongoing costs will increase if the trees are not well maintained, which drives up the likelihood and cost of mortality.
- The investment costs could be significantly lowered through more granular (localised) prioritisation, reducing the number of trees required. Therefore, the costs should be treated as 'upper bound' estimates.
- For the first time, we can confidently say that the dollar value of the benefits of greening metropolitan Melbourne are significant. For example, the value of more visually attractive and walkable streets (i.e. amenity value) is estimated at $11.8 billion over the next 30 years and the value of carbon sequestration is estimated at $1.2 billion.
- The expenditure invested to establish and maintain new vegetation in priority areas will create significant commercial activity and employment. The more the roll-out of the expenditure can be well-managed and smoothed, the greater the likelihood that industry (suppliers, installers, maintenance crew etc) can meet the demand in a more effective and efficient manner.
- The analysis has been undertaken at the metropolitan Melbourne scale. The same analysis can be applied at finer spatial scales (e.g. local government areas) and the results will differ for a variety of reasons, particularly due to the variation in current greening between different areas of the city. For example, the net benefits of increased canopy cover in areas with currently low levels of canopy will be higher than areas that already have high levels of cover. It would be prudent to run the analyses

outlined in this report for high-priority local government areas to inform any first tranche of investment. The scale of the analysis means it can be improved by finer-scale analysis, local knowledge, and a focus on critical local neighbourhood sites where the benefits are likely to be greatest.

- The real costs of planting trees and other vegetation differs markedly depending on the landscape, land use and the outcomes sought. Like all assets, vegetation needs to be maintained in the long-term if the benefits of the investment are to be realised. Simple estimates of the cost of planting trees provide a misleading underestimate of the long-term costs, and overlook the fact that the risk of failing to meet the heat reduction and enhanced biodiversity objectives is far greater when ongoing maintenance is not properly financed. The relativities between establishment and lifecycle operations and maintenance costs for different types and levels of greening are presented below (Table 11).

Table 11. Estimated costs for different types and levels of greening

Greening type	Priority	Value		
		Establishment (purchase and planting)	**Maintenance (over 30 years)** (watering, mortality, pruning etc)	**Total lifecycle costs**
Street tree	Urban heat reduction	$1,113 per tree	$1,485 per tree	$2,598 per tree
Street tree (with WSUD)	Urban heat reduction	$4,461 per tree	$1,961 per tree	$6,422 per tree
Biodiversity planting	Enhanced biodiversity (Low quality land)	$120,260 per ha	$69,060 per ha	$189,320 per ha
Biodiversity planting	Enhanced biodiversity (Moderate quality land)	$23,450 per ha	$4,870 per ha	$28,320 per ha
Biodiversity planting	Enhanced biodiversity (High quality land)	$5,955 per ha	$718 per ha	$6,673 per ha

Note: The cost of mortality is considered for both tree and biodiversity planting, and these costs involve the removal the re-establishment of the plant.

In summary, while the costs of urban greening and cooling are significant, separating them into their components of establishment and maintenance illustrate that merely putting trees and vegetation into the ground is insufficient, as maintenance costs constitute a significant proportion of the total lifecycle costs of greening. Adequate maintenance is crucial to ensure the long-term survival of urban vegetation and the full realisation of the benefits they provide.

4.2 Recommendations

1. There are 'no regrets' investments that could be made, particularly investing in urban vegetation in areas that are particularly at risk from extreme temperatures. The risk of such investment not stacking up are very low.
2. It would be prudent to run the analyses outlined in this report for high-priority local government areas, and smaller spatial scales to inform any first tranche of investment.
3. To bolster the findings from this project, more in-depth research is required (e.g., unit economic values of productivity losses) and the understanding some cause-and-effect relationships between more trees in the landscape and some benefit streams.

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Appendices

A

Identifying priority areas for greening

Phase 1 of the project (the prioritisation model development and application) was undertaken by Morphum Environmental, under the guidance of the Living Melbourne Project Management Team with oversight by the Project Working Group.

Priority scores were calculated for each Mesh Block for urban heat and biodiversity, as described below.

Urban heat

The urban heat score highlights Mesh Blocks with a high potential for heat reduction for vulnerable communities. The focus is on passive open spaces, local community and education facilities, and incorporates existing vegetation, heat mapping and vulnerability assessments undertaken by DELWP.

Each data set used to create the overall urban heat score is detailed in the table below, including the scoring criteria.

Criteria	Field Name	Threshold	Score
Thermal Hotspot	thermal_HS_1_score	Meshblock is within hotspot that is 10 degrees Celsius above baseline	2
	thermal_HS_2_score	Meshblock is within hotspot that is 7-10 degrees Celsius above baseline	1
Tree Canopy/Vegetation Cover	tree_canopy_1_score	Mesh block has very low canopy cover of less than 5%	2
	tree_canopy_2_score	Mesh block has low canopy cover of between 5% and 10%	1
Heat Vulnerability/Future Vulnerability	heat_vulnerab_1_score	Meshblock is within area of very high heat vulnerability and very low resilience	2
	heat_vulnerab_2_score	Meshblock is within area of high heat vulnerability and low resilience	1
Open Space	open_space_1_score	Meshblock contains or is within Park/recreation reserve/passive rec	1
Pedestrian/Exposure	ped_exp_1_score	Meshblock is within or contains a commercial zone (Any C zone)	1
	ped_exp_2_score	Meshblock contains or is adjacent to an educational facility	1
	ped_exp_3_score	Meshblock contains or is adjacent to community facilities	1
	ped_exp_4_score	Meshblock contains or is adjacent to community facilities	1

The following data sets (and processes) were used.

Thermal Hotspot

Data source

- HEAT_URBAN_HEAT_2018 (details available here)

Threshold for scoring

Two scores have been created:

thermal_HS_1_score: The Mesh Block is within a hotspot that is 10 degrees Celsius above baseline

This has been calculated by selecting all Mesh Blocks with a score greater than 10 for the attribute UHI18_M thermal_HS_2_score: The Mesh Block is within a hotspot that is 7 to 10 degrees Celsius above baseline

This has been calculated by selecting all Mesh Blocks with a score between 7 and 10 for the attribute UHI18_M

Tree Canopy/Vegetation Cover

Data source

- HEAT_URBAN_HEAT_2018 (details available here)

Threshold for scoring

Two scores have been created:

1) tree_canopy_1_score: The Mesh Block has a very low canopy cover of less than 5%.

This has been calculated by selecting all Mesh Blocks less than 5% in the column PERSHRTRE.

2) tree_canopy_2_score: Mesh Block has low canopy cover of between 5% and 10%.

This has been calculated by selecting all Mesh Blocks between 5% and 10% in the column PERSHRTRE.

Heat Vulnerability/Future Vulnerability

Data source

- HEAT_VULNERABILITY_INDEX_2018 (details available here)

Threshold for scoring

Two scores have been created:

1) heat_vulnerab_1_score: The Mesh Block is within an area of very high heat vulnerability and very low resilience.

This has been calculated by selecting all Mesh Blocks with a score of 5 in the column HVI_INDEX.

2) heat_vulnerab_2_score: The Mesh Block is within an area of high heat vulnerability and low resilience.

This has been calculated by selecting all Mesh Blocks with a score of 4 in the column HVI_INDEX.

Open Space

Data source

- VPA Open Space (details available here)

Threshold for scoring

The Mesh Block contains or is within:

- Park

- Recreation reserve
- Passive rec

Pedestrian/Exposure

Data source

- MICLUP_COMMERCIAL_EXT_JUN2020 (details available here)
- VMFOI (details available here)
- Rail stations (details available here)

Threshold for scoring

Four scores have been created:

ped_exp_1_score: The Mesh Block is within or contains a commercial zone (Any C zone)

ped_exp_2_score: The Mesh Block contains or is adjacent to an educational facility.

Educational facilities include: 'CHILD CARE', 'EDUCATION COMPLEX', 'FURTHER EDUCATION', 'KINDERGARTEN', 'PRIMARY AND SECONDARY SCHOOL', 'PRIMARY SCHOOL', 'SECONDARY SCHOOL', 'SPECIAL SCHOOL', 'TERTIARY INSTITUTION', 'UNIVERSITY'

ped_exp_3_score: This Mesh Block contains or is adjacent to community facilities.

Community facilities include: 'AGED CARE', 'CAMP GROUND', 'COMMUNITY CENTRE', 'COMMUNITY HEALTH CENTRE', 'GENERAL HOSPITAL', 'LIBRARY', 'MATERNAL AND CHILD HEALTH CENTRE', 'PLAYGROUND', 'SCHOOL CAMP', 'SPECIALISED HOSPITAL', 'SPORTSGROUND', 'SPORTS COMPLEX', 'SPORT FACILITY', 'SWIMMING POOL'

ped_exp_4_score: Mesh Block contains or is adjacent to train stations

Urban Biodiversity

The urban biodiversity score highlights Mesh Blocks with a high potential for enhancing urban biodiversity. The focus is on open spaces, natural and semi-natural open space, areas of conservation significance verified by local councils, waterway connectivity, connectivity assessments undertaken by DELWP/DEECA and land zoned for conversation purposes.

Each data set used to create the overall urban biodiversity score is detailed in the table below, including the scoring criteria.

Criteria	Field Name	Threshold	Score
Tree Canopy/ Vegetation Cover	tree_canopy_1_score	HEAT_URBAN_HEAT_2018	2
	tree_canopy_2_score		1
Open Space	open_space_1_score	VPA Open Space	1
Biodiversity	biodiversity_4_score		1
	biodiversity_8_score		2
	biodiversity_9_score		1
	biodiversity_12_score		2
	biodiversity_13_score		1
	biodiversity_10_score	Conservation Areas verified by Local Government ('Living Melbourne Dataset')	11
	biodiversity_11_score		10
	biodiversity_14_score	VMPLAN\PLAN_ZONE	2
	biodiversity_15_score		1
	biodiversity_17_score	BUSHBANK_BIORANK	2
	biodiversity_18_score		1
Waterways	waterways_score	Melbourne Water Port Phillip and Westernport Bio links mapping	2

Tree Canopy/Vegetation Cover

Data source

- HEAT_URBAN_HEAT_2018 (details available here)

Threshold for scoring

Two scores have been created:

1) tree_canopy_1_score: The Mesh Block has a very low canopy cover of less than 5%.

This has been calculated by selecting all Mesh Blocks less than 5% in the column PERSHRTRE.

2) tree_canopy_2_score: Mesh Block has low canopy cover of between 5% and 10%.

This has been calculated by selecting all Mesh Blocks between 5% and 10% in the column PERSHRTRE.

Open Space

Data source

- VPA Open Space (details available here)

Threshold for scoring

Six scores have been created:

1) Open_space_1_score: the Meshblock contains or is within Park/recreation reserve/passive rec

1) Biodiversity_4_score: the Meshblock contains or is within a Recreation Corridor

2) Biodiversity_8_score: the Meshblock contains or is within Natural and Semi Natural open space over 2ha in area (and has connectivity within 1km)

1) Biodiversity_9_score: the Meshblock contains or is within Natural and Semi Natural open space under 2ha in area (and has connectivity over 1 km)

2) Biodviersity_12_score: the Meshblock contains or is within All Conservation Reserves over 2ha in area (and has connectivity under 1 km)

1) Biodiversity_13_score: the Meshblock contains or is within a All Conservation Reserves GDA under 2ha in area (and has connectivity over 1 km)

Local Government Conservation Areas

Data source

- Conservation Areas Verified by Local Government
  - Note: This dataset was created by Living Melbourne (2020) by identifying conservation reserves in Melbourne metropolitan local government biodiversity, open space or conservation strategies. The quality of the final geospatial layer is directly related to the comprehensiveness and accuracy of the information included in the local government biodiversity, open space or conservation strategy.

Threshold for scoring

Two scores have been created

11) biodiversity_10_score: the Meshblock contains or is within polygons over 2ha

10) biodiversity_11_score: the Meshblock contains or is within polygons under 2ha

Land Use

Data source

- VMPLAN\PLAN_ZONE (details available here)

Threshold for scoring

2) biodiversity_14_score: the Meshblock contains or is within VMPLAN_GDA_over_2ha (and has connectivity under 1 km)

1) biodiversity_15_score: the Meshblock contains or is within VMPLAN_GDA_under_2ha (and has connectivity over 1 km)

Biodiversity

Data source

Bushbank Project Biodiversity Rank (details available here)

Threshold for scoring

2) biodiversity_17_score: the Meshblock contains or is within Very High over 2ha (and has connectivity under 1 km) OR Very High under 2ha (and has connectivity over 1 km)

1) biodiversity_18_score: the Meshblock contains or is within High over 2ha (and has connectivity under 1 km) OR High under 2ha (and has connectivity over 1 km)

Waterways

Data source

Melbourne Water Port Phillip and Westernport Bio links mapping (dataset may be available on request from Melbourne Water)

Threshold for scoring

2) Meshblock contains waterway

B

Estimating the trees and vegetation needed to green priority areas

Setting greening thresholds

Canopy greening thresholds for individual Mesh Blocks were set for each Mesh Block category (MB_CAT). Using the Vegetation Cover–Modified Mesh Block (2018) data set, the 90th percentile of canopy cover (per Mesh Block category) was calculated and taken to be an aspirational, yet realistic threshold for Mesh Block canopy cover.

In addition to an overall canopy greening threshold for Mesh Blocks, it was necessary to assess the capacity of road reserves within each land use category for greening. The 90th canopy cover percentiles of 'infrastructure' modified Mesh Blocks (which comprise theVegetation Cover–Modified Mesh Block (2018) data set), grouped by Mesh Block category, were calculated and used as an estimate for the capacity of road corridors (by land use) to accommodate additional trees. For the purposes of this analysis, the area of a road reserve within a Mesh Block was considered as a whole. Streets were not assessed on an individual basis.

Results of the analysis are shown in the tables below.

Mesh Block canopy cover 90th percentile (by land use, 2018)

Mesh Block land use	Mesh Block canopy cover 90th percentile	Road reserve canopy cover 90th percentile (used to assess capacity for greening)
Residential	26%	30%
Commercial	16%	19%
Industrial	12%	15%
Education	27%	31%
Hospital/medical	24%	27%
Parkland	40%	34%
Primary production	8%	34%
Transport	32%	22%
Water	8%	16%
Other:	25%	30%

To account for the area within a Mesh Block able to accommodate additional trees in the public realm, we also estimated the capacity of different public open space typologies for greening. For example, open space used as a sports field or cemetery will not be able to achieve the same level of canopy cover as a natural/semi-natural open space or neighbourhood park.

The **VPA Open Space** spatial data set was used to assess the potential within public open space and restricted public land for greening Mesh Blocks. To account for outliers and apply consistency, the 90th percentile of canopy cover within public open space (grouped by VPA open space category) was also taken as an indication of that particular open space typology's capacity for new trees.

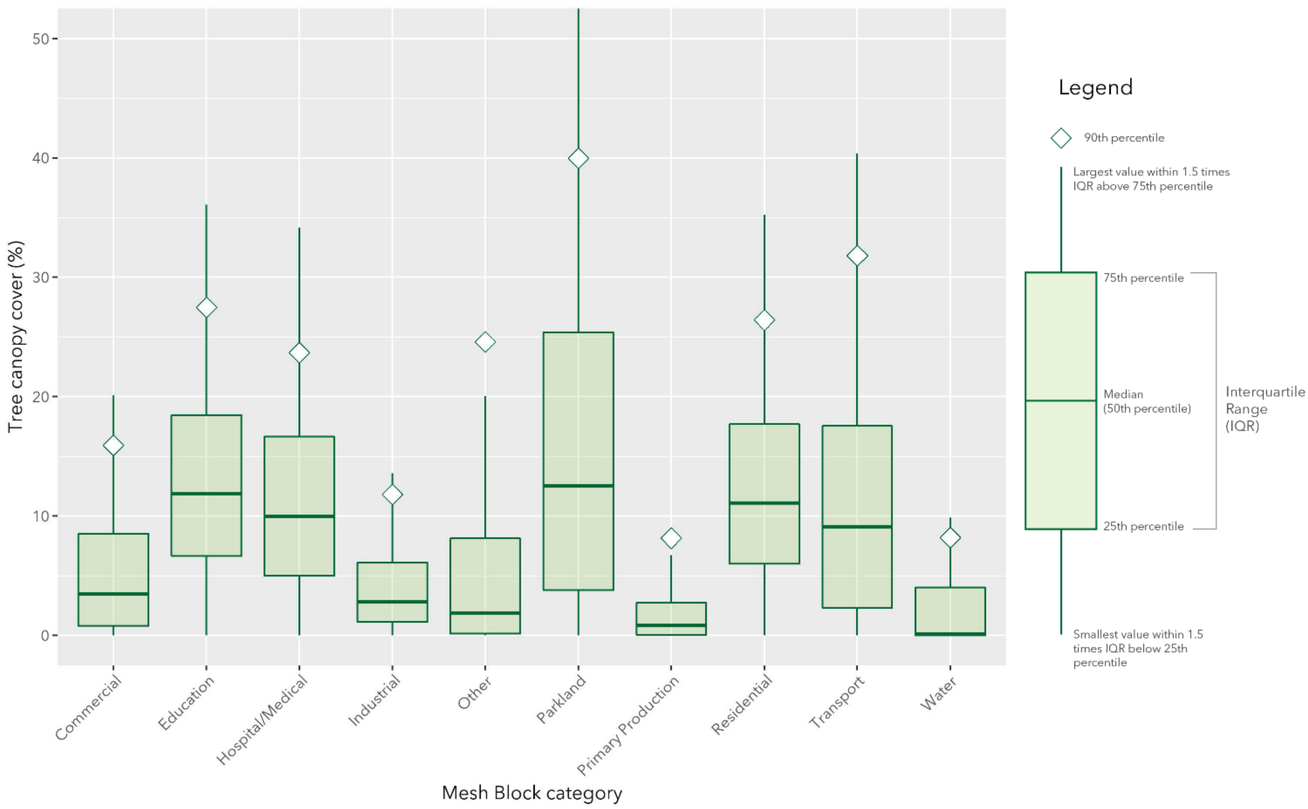
Golf courses, race courses and open space polygons with an area of less that 0.01 hectares were excluded from this analysis.

Canopy cover of each public open space was computed using a fusion of **Vicmap Vegetation Tree Urban Point** and **Vicmap Vegetation Tree Extent** data sets.

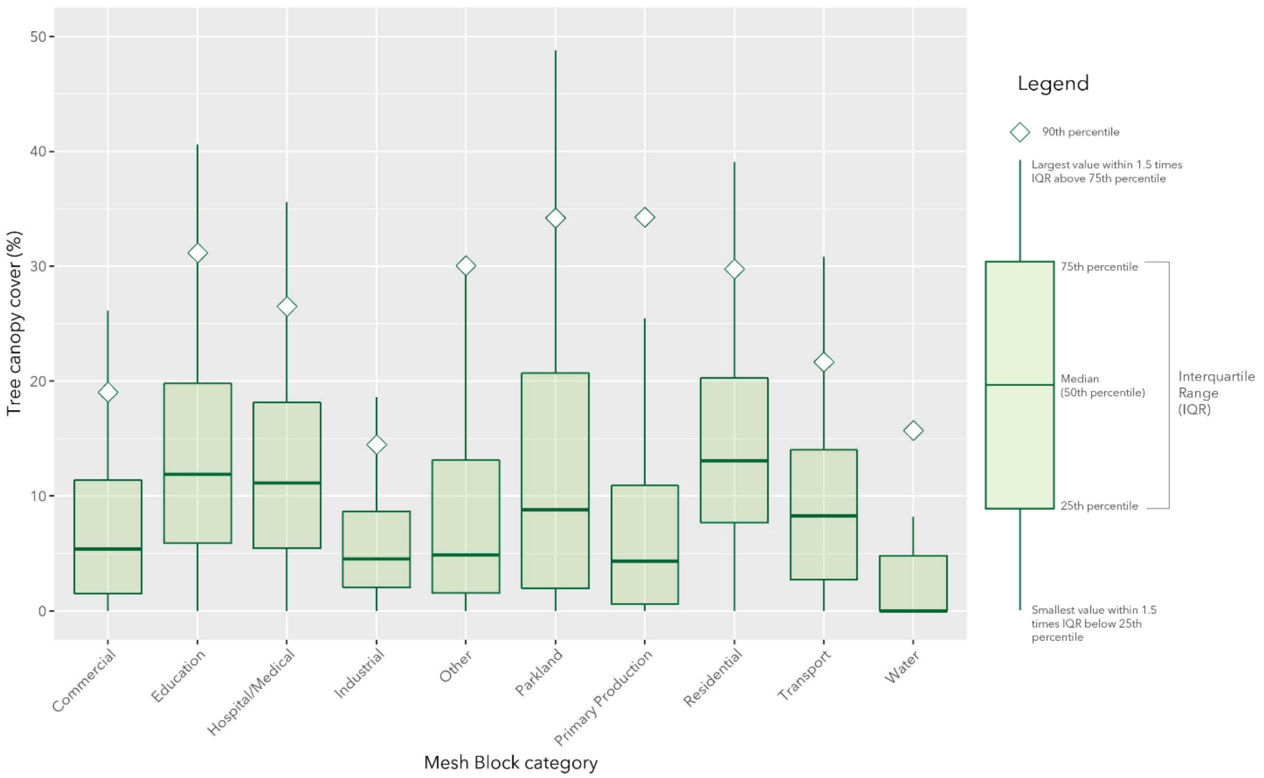
Public open space canopy cover capacity (open space canopy cover 90th percentile, 2018)

Open space type	Canopy cover 90th percentile
Cemeteries	57%
Civic squares	47%
Conservation reserves	100%
Government schools	38%
Natural/semi-natural	98%
Parks and gardens	72%
Public housing reserves	45%
Recreation corridor	74%
Services/utilities reserves	77%
Sports fields	50%
Tertiary institutions	38%
Transport reservations	84%

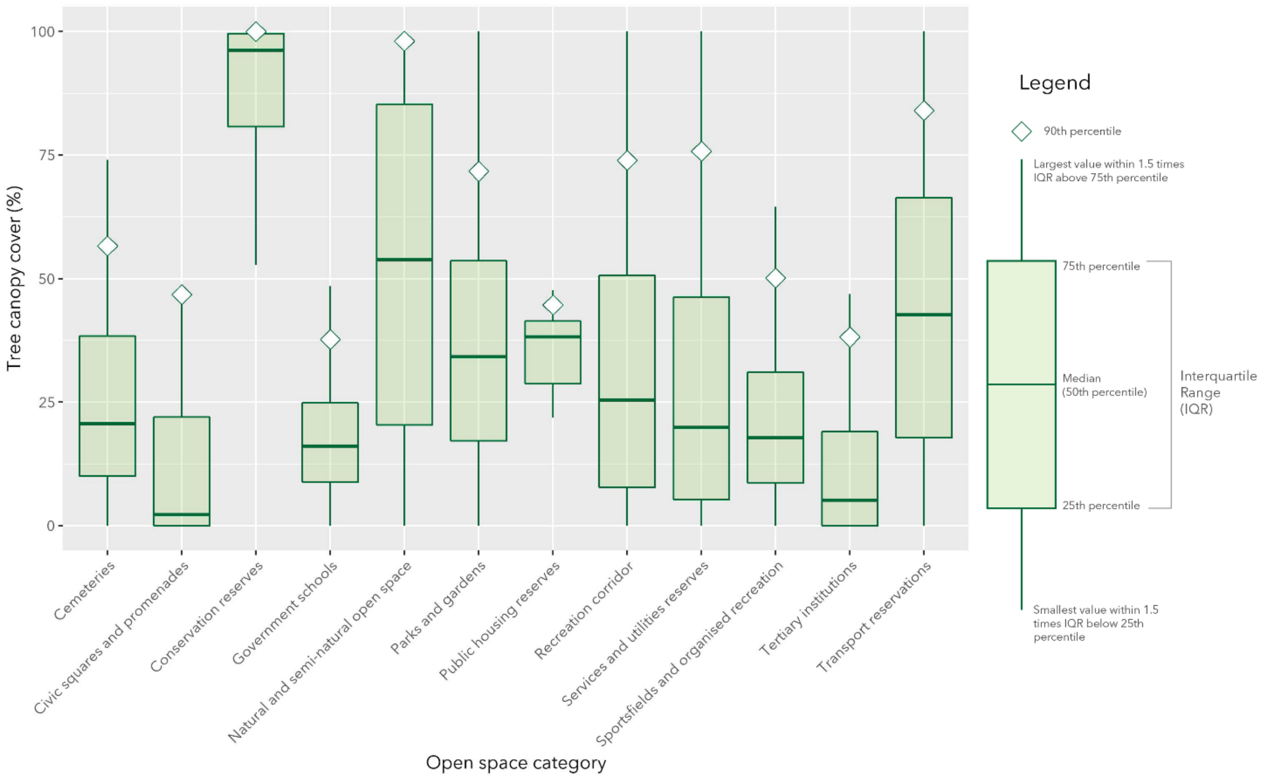
More details on the range of tree canopy cover by Mesh Block category, road reserve and open space category are shown in the figures below.



Tree canopy cover in metropolitan Melbourne by Mesh Block category (whole Mesh Block). Data: Vegetation Cover 2018



Road reserve tree canopy cover in metropolitan Melbourne by Mesh Block category
Data: Vegetation Cover 2018



Open space tree canopy cover in metropolitan Melbourne by VPA open space category. Note the very high canopy cover in conservation reserves, reflecting their relatively undisturbed character.
Data: Vegetation Cover 2018

Spatial analysis to quantify the current level of tree canopy/greening and the number of trees needed to meet the greening thresholds was undertaken for every heat reduction priority Mesh Block using QGIS and documented using Python scripting and R scripting.

Data sets used:

- **Vicmap Vegetation Tree Urban Point**
- **Vicmap Vegetation Tree Extent**
- **VPA Open Space**
- **Living Melbourne Prioritisation Outputs (Mesh Blocks)**
- **Vicmap Property Road Casement**
- **Road Partition Dissolved (RMIT)**
- **Speed Zones (Vicroads)**

Priority heat Mesh Block analysis

8,261 Mesh Blocks within the urban growth boundary were selected for analysis based on need for heat reduction. These Mesh Blocks were selected using priority scores—Mesh Blocks with a total heat score more than or equal to 5 (with a maximum score of 11) were defined as priority heat reduction Mesh Blocks.

In addition, Mesh Blocks with the category 'Primary Production' and 'Residential' Mesh Blocks with an area greater than 1 km^2 were excluded from the analysis.

Street tree analysis

- To assess the current state of canopy cover within road reserves, road reserves were dissolved by Mesh Block code, meaning that the entire area of road reserve within a Mesh Block was considered as a whole.
- Overlap analysis was undertaken using the dissolved road reserves and a fusion of **Vicmap Vegetation Tree Urban Point** –polygonised using the X and Y canopy information for each point within the data set–and **Vicmap Vegetation Tree Extent** data sets. This resulted in the computation of current street tree canopy (in area and percentage terms) per heat priority Mesh Block.
- The number of street trees in each Mesh Block was calculated by counting the number of **Vicmap Vegetation Tree Urban Point** features intersecting road reserves. This meant that only trees with their centre (i.e., trunk) within a road reserve were counted as street trees. Those on private property that had portions of their canopy intersecting with the road reserve were not.
- The theoretical capacity of the Mesh Block for street trees was then estimated using the length of road reserve suitable for planting (calculated using road partition polygons, **excluding roads with a speed limit Metropolitan than 60km/h** and **excluding small service lanes**)–**assuming a standard tree spacing of 10 metres.** In addition, road median reserves were not included in this analysis due to data availability.
- Outputs from this stage of the analysis (for each priority heat Mesh Block):
    - Length of street suitable for street tree planting
    - Area of tree canopy within road reserve
    - Percentage of road reserve covered by tree canopy
    - Number of street trees
    - Total street tree capacity

Open space analysis

- Canopy cover was calculated for each polygon within the **VPA Open Space** spatial data set that had the OS_TYPE 'Public open space' or 'Restricted public land' and was not a golf course or a racecourse. This was done in the same manner as Mesh Blocks and streets–performing overlap analysis using a fusion of **Vicmap Vegetation Tree Urban Point** and **Vicmap Vegetation Tree Extent**.
- Using **Vicmap Vegetation Tree Urban Point**, the number of trees in each open space polygon was also calculated.
- Canopy cover and number of trees were assessed (by Mesh Block) for each open space typology separately, using each of the 12 open space categories ('OS_CATEGOR'):
  - Cemeteries
  - Civic squares and promenades
  - Conservation reserves
  - Government schools
  - Public housing reserves
  - Natural and semi-natural open space
  - Parks and gardens
  - Recreation corridor
  - Services and utilities reserves
  - Sports fields and organised recreation
  - Tertiary institutions
  - Transport reservations

Enhanced biodiversity analysis

The Victorian Government developed specialised decision support tools that bring together the best information available, to help inform how we prioritise land management actions that protect the future of Victoria's unique plants, animals, and habitats. One of the data sets available in the Strategic Management Prospects decision support tool is the Biodiversity Value Rank. This was developed from the DELWP (now DEECA) Strategic Management Prospects revegetation benefit model that predicts the benefits of suitable revegetation to 4,200 species and preferences connectivity. This data set was used as it spatially prioritises beneficial revegetation actions at a State level. A limitation of this analysis is that it was unable to isolate any comprehensive data set that identified and prioritised metropolitan conservation reserves and natural spaces with conservation values within a Melbourne metropolitan context.

C

Estimating the value of the benefits of greening

The table below summarises the quantified benefits in this project and describes at a high level, the method for estimating the magnitude of the benefits. The benefits were incorporated into the cost-benefit analysis.

Summary of benefits quantified in the priority urban greening analysis.

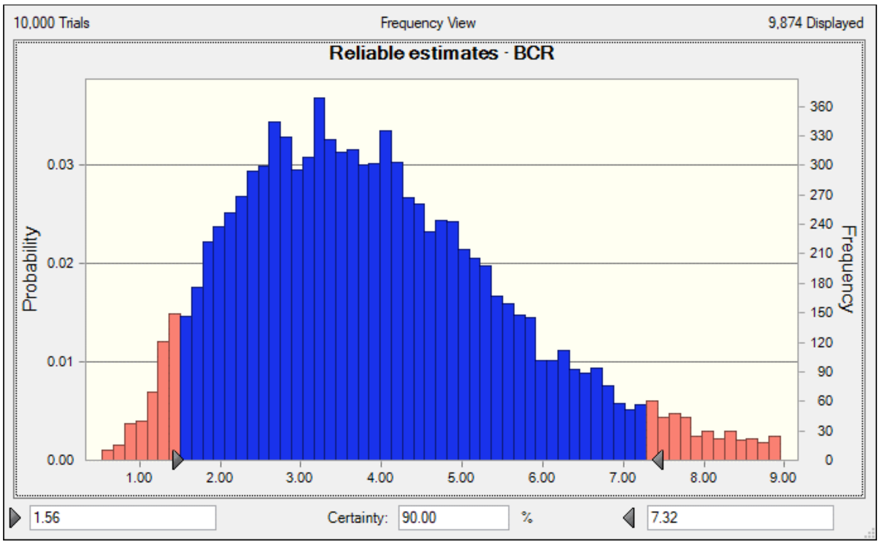
Benefit	Quantifying the benefit of one tree
Amenity value of trees	[A] Tree maturity adjustment factor [B] Number of properties within 20 m proximity to urban trees [C] Percentage uplift for those properties **A x B x C**
Carbon sequestration	[A] Tree maturity adjustment factor [B] Carbon sequestered per mature tree [C] Australian Carbon Credit Unit Price per ton of carbon **A x B x C**
Avoided expenditure on space cooling	[A] Average energy expenditure per household [B] Estimated average energy savings provided per tree to a household within sufficiently close proximity **A x B**
Avoided productivity losses	[A] Heat reduction benefit provided by increased canopy cover [B] Number of workers who benefit from heat reduction effect [C] Economic benefit from reducing absenteeism and presenteeism **A x B x C**
Reduced management costs from stormwater runoff	A] Tree maturity adjustment factor [B] Average pollutant/stormwater retained per tree [C] Avoided stormwater management and treatment cost **A x B x C**

D

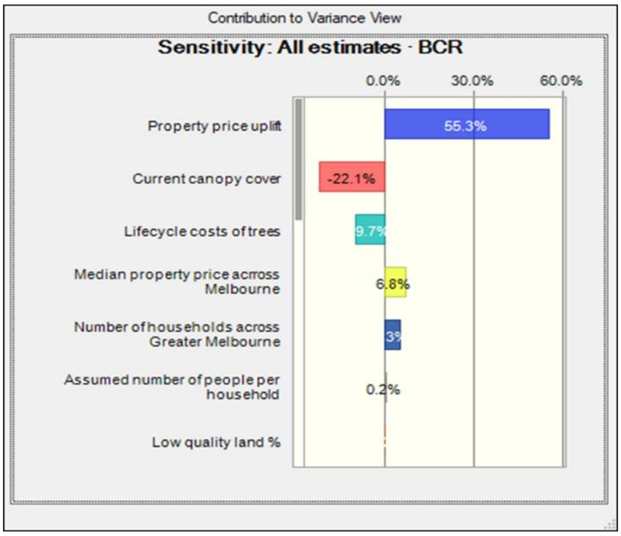
Overview of Monte Carlo simulation

Monte Carlo simulation is a sophisticated approach to capturing the uncertainty with parameters within a CBA. In scoping the associated costs and benefits of a project, ranges for each parameter can be established to reflect any risk and uncertainty. These values then interact with each other in multiple iterations (e.g., 20,000 iterations) of the model to determine the impact of the aggregate uncertainty. Monte Carlo simulations are conducted using specific applications or spreadsheet plug-ins, which require expert practitioners.

The simulations allow the practitioner to generate metrics (such as confidence intervals) and insightful charts that effectively illustrate the uncertainty associated with the CBA results. One example is a probability distribution, which demonstrates the likelihood of outcomes within the ranges and confidence intervals (see figure below).



The range and distribution of results provide clear illustration of the uncertainty associated with individual projects and thus, enables a more informed comparison between the projects and allows decision-makers/investors to pursue projects which are reflective of their risk appetite. Monte Carlo simulations also enable the identification of how much variability in estimates is attributable to individual input parameter or assumptions (an example of which is shown in the figure below) and provides a better reflection of the relative impact of each parameter on the final estimate.



This is particularly useful when considering what issues to focus on when attempting to improve estimates in the future.

E

Greening typologies