Urban Melbourne Environmental-Economic Account

Technical Report

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This project was undertaken by the economics team in DEECA's Strategy and Performance Division to provide decision makers with an evidence base on the socio-economic value of green-blue infrastructure in Melbourne.

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We acknowledge and respect Victorian Traditional Owners as the original custodians of Victoria's land and waters, their unique ability to care for Country and deep spiritual connection to it.

We honour Elders past and present whose knowledge and wisdom has ensured the continuation of culture and traditional practices.

DEECA is committed to genuinely partnering with Victorian Traditional Owners and Victoria's Aboriginal community to progress their aspirations.

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Contents

List of abbreviations and acronyms

ABS	Australian Bureau of Statistics
ASGS	Australian Statistical Geography Standard
BSU	Basic Spatial Units
CBiCS	Combined Biotope Classification Scheme
CICES	Common International Classification of Ecosystem Services (European Environment Agency)
DEECA	Department of Energy, Environment and Climate Action
DELWP	Department of Environment, Land, Water and Planning
EA	Ecosystem Assets
EEA	Environmental-Economic Accounts
EVC	Ecological Vegetation Classes
GA	Geographical Areas
GBI	Green-blue infrastructure
GCCSA	Greater Capital City Statistical Area
GVA	Gross Value Added
IPBES	Intergovernmental Panel on Biodiversity and Ecosystem Services
LGA	Local Government Area
MAES	Mapping and Assessment of Ecosystems and their Services (by European Commission)
OECD	Organisation for Economic Co-operation and Development
QALY	Quality adjusted life year
SEEA	System of Environmental-Economic Accounting (UN)
SEEA-EA	System of Environmental-Economic Accounting – Ecosystem accounts
VLCTS	Victorian Land Cover Time Series
VLUIS	Victorian Land Use Information System
VOLY	Value of a Life Year
WTP	Willingness to Pay

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Headline results: Urban Melbourne Environmental-Economic Account

UN System of Environmental-Economic Accounting (SEEA) Framework

Status of ecosystem assets in urban Melbourne

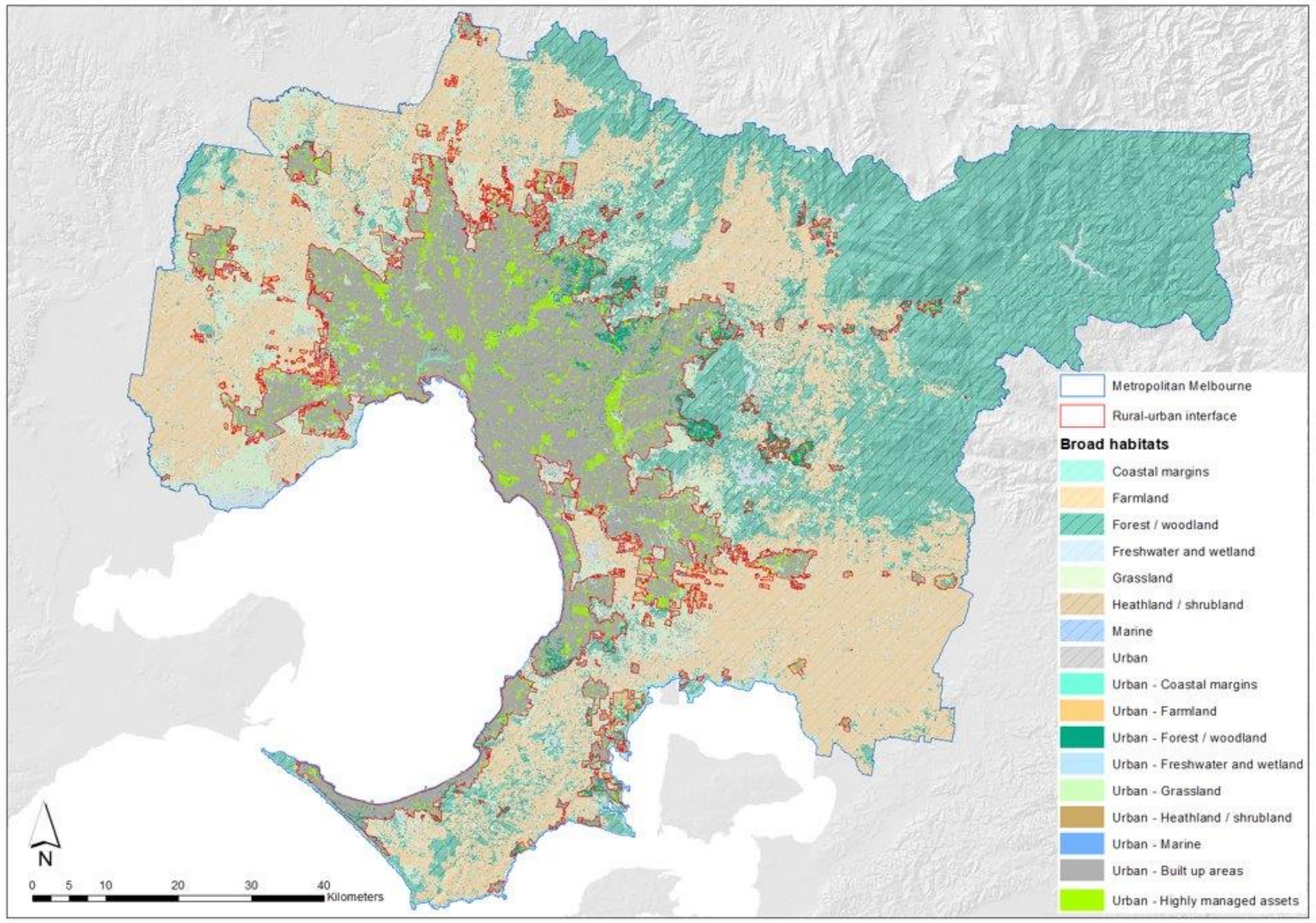
Asset extent

Measure spatial extent of ecosystem assets

Asset condition

Measure health of ecosystem assets

Urban Melbourne EEA Outputs



Ecological condition

- **Biodiversity**
  - 111 threatened flora and 103 threatened fauna species
  - 24 out of 100 habitat importance for threatened species
  - 8 out of 100 native vegetation score
- **Soil**
  - 2,474 ha of land at high landslip risk
- **Water**
  - 6 out of 50 index of stream condition score
- **Carbon**
  - 20.4 million tonnes of CO_2e stored in ecosystems

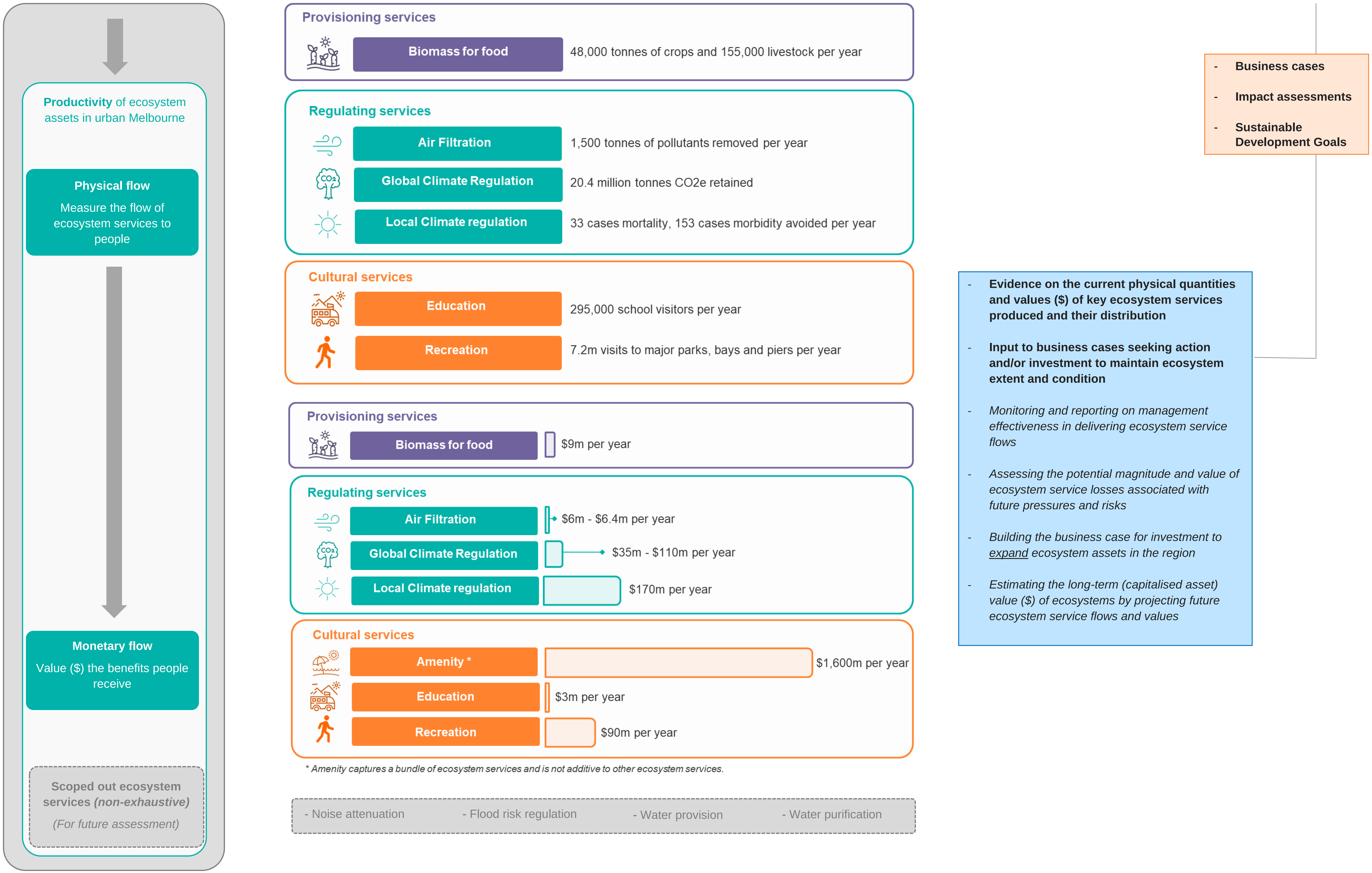
Socio-economic characteristics

- **Location**
  - 57% of dwellings within 400m of public open space
- **Cultural assets**
  - 907 assets of historical cultural heritage
- **Governance and management**
  - Over 600ha of national parks / nature reserves
- **Built assets**
  - 894km of walking tracks
  - 35 piers and jetties

Urban Melbourne EEA Use (Current / *Future*)

- **Evidence on the current (2019) extent and distribution of ecosystems**
- *Monitoring and reporting on management effectiveness in meeting extent targets*
- *Identifying ecosystems at risk of future pressures*
- *Identifying ecosystem restoration opportunities through comparison with historical extent*
- *Identifying key ecological interactions across space and time*

- **Evidence on the current condition of ecosystems across the region**
- **Capturing ecosystems' intrinsic value**
- **Identifying ecosystem restoration opportunities**
- *Monitoring and reporting on management effectiveness in meeting condition targets*
- *Understanding how sustainable our use of the regions' ecosystems is over time*
- *Identifying ecosystems that are currently adversely affected by pressures*
- *Identifying key ecological interactions across space and time*
- *As a basis for future research to explore "critical ecosystem characteristics" that underpin productivity*



Productivity of ecosystem assets in urban Melbourne
Physical flow
Measure the flow of ecosystem services to people
Monetary flow
Value ($) the benefits people receive
Scoped out ecosystem services (non-exhaustive)
(For future assessment)
Provisioning services
Biomass for food
48,000 tonnes of crops and 155,000 livestock per year
Regulating services
Air Filtration
1,500 tonnes of pollutants removed per year
Global Climate Regulation
20.4 million tonnes CO2e retained
Local Climate regulation
33 cases mortality, 153 cases morbidity avoided per year
Cultural services
Education
295,000 school visitors per year
Recreation
7.2m visits to major parks, bays and piers per year
Provisioning services
Biomass for food
$9m per year
Regulating services
Air Filtration
$6m - $6.4m per year
Global Climate Regulation
$35m - $110m per year
Local Climate regulation
$170m per year
Cultural services
Amenity *
$1,600m per year
Education
$3m per year
Recreation
$90m per year
* Amenity captures a bundle of ecosystem services and is not additive to other ecosystem services.
- Noise attenuation
- Flood risk regulation
- Water provision
- Water purification
- Business cases
- Impact assessments
- Sustainable Development Goals
- Evidence on the current physical quantities and values ($) of key ecosystem services produced and their distribution
- Input to business cases seeking action and/or investment to maintain ecosystem extent and condition
- Monitoring and reporting on management effectiveness in delivering ecosystem service flows
- Assessing the potential magnitude and value of ecosystem service losses associated with future pressures and risks
- Building the business case for investment to expand ecosystem assets in the region
- Estimating the long-term (capitalised asset) value ($) of ecosystems by projecting future ecosystem service flows and values

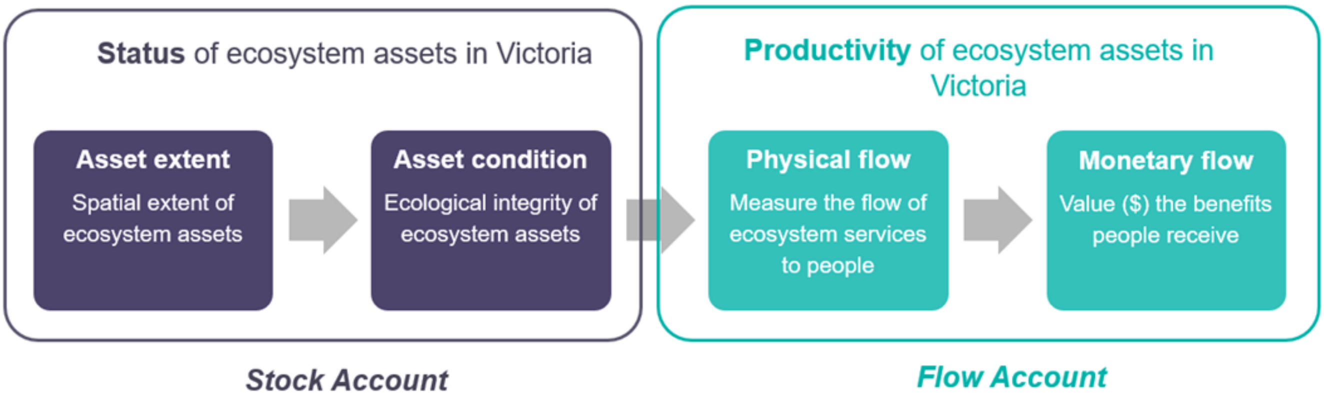
Executive Summary

The value of green and blue infrastructure in urban environments is well established and widely acknowledged. Urban parks, market gardens, street trees, rivers and lakes provide food and recreational opportunities, as well as regulate noise, air quality and local and global climates. These environmental goods and services lead to a range of health and wellbeing benefits, as well as financial benefits, that can be quantified and valued using economic analysis.
There is a significant amount of data and analysis on the socio-economic value of green and blue infrastructure in Victoria and Melbourne, however it is not currently consolidated or articulated in a way that is useful for decision makers. Addressing this evidence gap by developing an Urban Melbourne environmental-economic account was supported by DELWP's green infrastructure working group and received sign-off from DELWP's Senior Leadership Team in 2019.

This project develops a baseline environmental-economic account for urban Melbourne that aligns with the UN System of Environmental Economic Accounts – Ecosystem Accounts guidance (UN, 2021). The UN SEEA is a framework for reporting on links between the environment and the economy using internationally agreed accounting concepts.

Ecosystem accounts are a type of environmental-economic account (EEA) that take stock of current ecosystem assets – in terms of their extent, location, and condition – and quantify and value the flow of ecosystem services that these assets generate for people, who enjoy benefits from them. Figure S1 sets out the ecosystem framework. For the purpose of this work, reference will be made to the Urban Melbourne Environmental-Economic Account (urban Melbourne EEA).

Figure S1. Environmental-Economic Accounts - Ecosystem accounting framework



This environmental-economic account for urban Melbourne shows that the ecosystems within the urban Melbourne EEA boundary are important for threatened flora and fauna and deliver a range of ecosystem services that provide significant socio-economic value to society.

The methodological approach to urban Melbourne EEA development was agreed with the project steering group (DELWP's green infrastructure working group) based on a review of economic assessments of urban ecosystem assets globally, international guidance on environmental-economic accounting as well as existing information on ecosystem status and productivity within Melbourne.

Environmental-economic accounts are typically developed iteratively, with initial accounts focusing on priority areas that are subsequently expanded and refined over time. This urban Melbourne EEA has made use of the best available information at the time of the study. Given that no data has been collected specifically for the study region or for the purpose of developing an EEA, justifiable assumptions have been adopted based on data (where possible) or expert judgement in order to align readily available information with the urban Melbourne EEA boundary and with the principles of SEEA as best as possible. Based on this approach and the uncertainties associated with this, the results should be interpreted as indicative order or magnitude estimates that provide a proof-of-concept urban Melbourne EEA and a basis for future work to refine and expand the accounts to provide useful evidence on the status and productivity of ecosystem assets in the region.

The account has been developed for 2019 on the basis that this is the most recent year for which most of the necessary information exists (including the latest ecosystem extent data in Victoria) and ensures that the account is not skewed by the impact of COVID-19. Information for 2019 has been used where possible and where 2019 data is not available it is taken from the years 2015 to 2021 (some condition data precedes this but is presented for completeness). The account could therefore be more accurately described as being representative of ecosystem status and productivity over the period 2015 to 2021.

The urban Melbourne EEA region consists mostly of built-up areas / grey infrastructure (approximately 127,000 hectares or 59 per cent). The remaining approximately 88,000 hectares (or 41 per cent) consists of the natural ecosystem assets within the urban extent. Highly managed assets, including parks, open space, reserves and sports and recreation assets, make up the largest urban ecosystem asset type (approximately 32,000 hectares or 15 per cent), and integrated green infrastructure, namely street / city tree canopy, cover approximately 16,000 hectares (or 7 per cent) (refer to Table S1 for the headline extent account). The spatial distribution of the asset extent within the urban Melbourne EEA area is defined by the outer perimeter of the 'Rural-urban interface' (DELWP, 2018) (Figure S2).

Key insights from the information compiled in the ecosystem condition account (refer to Table S2 for headline condition account) are:

- Native vegetation condition scores (measured from 0-100) (DELWP 2017) across the study area generally reflect the very high level of vegetation disturbance and average 8 out of 100 for the Melbourne EEA area.
- Habitat importance for threatened species is measured using 'Strategic Biodiversity Values' data (DELWP 2016c). The data tells a similar story to the native vegetation condition scores, with the very high level of disturbance to native vegetation being the main driver of low scores, averaging 24 out of 100 for the Melbourne EEA area.
- Data from the Victorian Biodiversity Atlas (DELWP 2021) records the observation of 111 individual species of threatened flora and 103 individual species of threatened fauna located within the urban Melbourne EEA study area.
- Vegetation cover data was sourced from the Cooling and Greening Melbourne project (DELWP 2019a) shows that vegetation cover across urban Melbourne varies significantly. The inner eastern suburbs have much higher proportions of tree coverage when compared to the newly developed areas of north-western and south-eastern Melbourne. This has implications for urban cooling capacity and amenity.
- Above ground live biomass data across Victoria's public land areas has been created by the Victorian Forest Monitoring Program (DELWP 2018b). The data for the study area shows a stable level of biomass from 2012 until 2017 which suggests limited major disturbances within the public land estate of urban Melbourne.
- Coastal acid sulphate soils (CASS) occur naturally across large parts of Victoria's coastline and if left undisturbed pose little risk to the environment and built assets. If disturbed however water draining from such sites can become highly corrosive damaging ecosystems and built assets. The Melbourne EEA study area contains 9,691 hectares of land susceptible to CASS (DJPR 2003).

- 2,474 hectares of land within the urban Melbourne EEA study area is classified as highly susceptible to landslide (DJPR and A.Miner 2017). The highest risk locations are concentrated around the Hastings area which comprises just 1.3% of the total urban Melbourne EEA study area.
- The Victorian Index of Stream Condition (ISC) (DELWP 2010) shows that within the urban Melbourne EEA study area 81% of the streams and rivers were in poor to very poor condition, 19% in moderate condition and no streams were in good or excellent condition. The mean urban Melbourne EEA study area 2010 ISC score was 6 out of 50.
- The Victorian Index of Estuary Condition (IEC) (DELWP 2021b) shows that of the 19 estuaries within the urban Melbourne EEA study area none were in good or excellent condition, 3 were in moderate condition, 11 were in poor condition and 5 were in very poor condition.
- Within the urban Melbourne EEA study area there are 213 flood water retarding basins that collectively cover 986 hectares (Melbourne Water, 2019).
- The urban Melbourne EEA study area stored 5.5 million tonnes of carbon in 2019 (DISER 2021), the more heavily vegetated eastern suburbs and vegetated river corridor's providing the bulk of that storage.
- Light pollution is commonly expressed using the Bortle scale, a nine level numeric scale that measures the night sky's brightness through visibility of celestial objects with level 1 being a true dark sky with no interference through to 9 being a typical inner city location where only the brightest stars are visible. The majority of the urban Melbourne EEA study area is class 7 with the Melbourne CBD class 9.
- Data showing the percentage of houses within 400 metres of open space (AUO, 2020) shows much variation across the urban Melbourne EEA study area. Eastern, northern and far eastern Melbourne have relatively low access to open space with large areas displaying less than twenty percent of all houses within 400 meters of open space.
- Analysis of data from the Victorian Heritage Database (DELWP 2019c) shows that there are 907 recorded historic cultural heritage sites that wholly or partly intersect with open space within the urban Melbourne EEA study area.
- The urban Melbourne EEA study area intersects with three Designated Water Supply Catchment areas totalling 73 hectares, all within the Greenvale Reservoir area (DELWP, 2018c).
- There are three Ramsar listed wetlands within or intersecting the urban Melbourne EEA study area (Edithvale-Seaford Wetlands, Port Phillip Bay {western shoreline} and Western Port. (DEE, 2017).
- Within or intersecting the urban Melbourne EEA study area there are 26 individually named National Parks or Nature Conservation Reserves totalling just over 600 hectares.
- Within the urban Melbourne EEA study area there are 35 public piers and jetties (DELWP, 2020) providing recreational opportunities for fishing, swimming, site seeing, nature observation and boating.
- Within the urban Melbourne EEA study area there are 101 public boat access points such as ramps, slipways and launches (DELWP, 2020) providing recreational opportunities for sailing and boating.
- Within or immediately adjacent to the urban Melbourne EEA study area there are 77 individually classified boating restriction zones totalling approximately 3,659 hectares (DELWP, 2020).
- There are 894 kilometres of walking tracks and 1,107 kilometres of bicycle paths within the urban Melbourne EEA study area (DELWP 2021d).

Key insights from the information compiled in the flow accounts include (refer to Table S3 for the headline physical and monetary values estimated for each ecosystem service):

- The analysis undertaken for the urban Melbourne EEA suggests that the ecosystems of the region deliver ecosystem services that are worth at least $300 million per year, with an alternative estimate suggesting that the ecosystem services could be worth at least $1.6 billion per year. The (at least) $300 million estimate excludes the amenity valuation as this estimate potentially captures values from other ecosystem services, including those which have been assessed as part of this account. The alternative estimate of (at least) $1.6 billion combines the valuations of amenity and global climate regulation, as the global climate regulation service is the only assessed ecosystem service that does not specifically provide benefits on a localised scale, thus the benefits of the global climate regulating services of ecosystem assets would not factor into the value that local residents place on green space that is captured in the estimated house price premiums associated with proximity to green space.

- The “amenity” value of green infrastructure is estimated to be the most highly valued ecosystem service. However, it is unclear precisely what “bundle of ecosystem services” are captured within this approach and caution needs to be used when using this “amenity” value alongside other estimates of the value of ecosystem services from urban ecosystem assets in Melbourne. The estimated amenity value of metropolitan parks within the urban Melbourne EEA region is estimated to be $0.5 billion per year and $1 billion per year for sports and recreation parks. This value is a demonstration of residents’ willingness to pay to live closer to these particular types of parks, which will in part be determined by their ability to pay. The interpretation of this value for policy decision making needs careful consideration to avoid the conclusion that society values parks more highly in affluent areas compared to less affluent areas, and it is recommended that these results are not used as the sole measure of benefits of green space, including in any prioritisation process for comparisons of the benefits of new parks in different locations.
- Air filtration regulation service by urban trees benefits communities by reducing exposure to harmful pollutants which in turn improves health outcomes. There are an estimated 6.9 million trees within the urban Melbourne EEA region which remove over 1,500 tonnes of pollutants per year from the air, across the pollutants: NO_2, SO_2, PM10, CO, PM2.5 and O_3. The monetary value of pollutants removed by urban trees in a year has been estimated for NO_2, SO_2 and $PM_{2.5}$ at $6 million to $6.4 million based on damage costs related to morbidity and mortality from pollution.
- Educational visits supported by the ecosystems of the urban Melbourne EEA region are estimated to total 6,500 (or almost 300,000 student visitors) in 2019, with most frequently visited suburbs within the urban Melbourne for nature-related educational trips in 2019 were Parkville (651 visits), Melbourne (349 visits) and Brunswick East (185 visits). The monetary value of these visits are a very conservative representation of the value of these educational trips to society based on activity expenditures alone, estimated at $3.4 million per year, and not the true economic value of educational benefits associated with these trips including improved learning and life skills, mental health benefits and environmental awareness.
- Production of food biomass in the urban Melbourne EEA region is supported by ecosystems which provide a range of ecological functions that enable species to live and grow. Analysis for this urban Melbourne EEA suggests there is a substantial agricultural production within the urban Melbourne EEA region including 48,000 tonnes of arable output (crops and hay) and 155,000 livestock valued at around $8.7 million a year based on resource rent provided by urban ecosystems (i.e. isolating the contribution of the ecosystem from other inputs such as labour and machinery). Of this $8.7 million, $7.1 million is the contribution from the production of food, while $1.6 million is from other production such as hay, flowers or turf. The value to households of community garden production in the urban Melbourne EEA region is estimated to be worth around $60,000 per year based on avoided costs alone (i.e. not accounting for the range of other benefits of community garden production).
- Global climate regulation service is estimated based on avoided release of carbon stocks which total 20.4 million tCO_2e in the urban Melbourne EEA area. This ecosystem service is valued at between $35 million per year based on the avoided cost of greenhouse gas abatement or offset measures and $106 million per year based on the avoided damages to society (social cost of carbon).
- The local climate regulating service of ecosystem assets in the urban Melbourne EEA region is estimated through the reduction in number of days at high temperatures above 30 degree centigrade and valued based on the avoided adverse health impacts and productivity losses. The aggregated effect of ecosystem assets (urban rivers, lakes, ponds, wetlands as well as parks and gardens, street trees and green roofs) on temperatures (°C) across urban Melbourne in 2019 is estimated at -0.23°C, which is estimated to avoid 33 additional deaths, 37 additional ambulance attendances and 116 additional emergency department

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presentations by 64 year old’s and over due to extreme heat under a "without ecosystem scenario". The estimated value of adverse health outcomes associated with these events is $168 million. The gain in productivity due to the presence of green-blue infrastructure and its cooling effect is estimated to be worth $5 million per year.

- The partial estimate of recreational visits that can be attributed to the existence of ecosystems within the urban Melbourne EEA region is 7.4 million per year in 2018-19. Approximately a third of these visits are estimated to be to the Royal Melbourne botanic gardens (2.1 million per year). This only includes visits to seven parks, one pier and the botanic gardens and is therefore an underestimate of the total number of recreational visits to urban ecosystems in Melbourne Approximately 770,000 of these visits are estimated to be “active visits” that meet certain physical activity guidelines (and therefore provide a health benefit) undertaken by around 65,000 visitors (i.e. the same people visiting urban ecosystems for physical exercise multiple times a year). The economic value of recreation in the urban Melbourne EEA region is approximately $91 million a year, based on the estimated:

  a. Welfare value of recreation within the urban Melbourne EEA region of $86 million in 2018-19.

  b. Improved productivity of the Australian labour force from “active visits” of $1 million in 2018-19.

  c. Avoided medical costs to Australian households and government of $4 million in 2018-19 from “active visits”.

Table S4 shows the aggregated supply and use table which captures the “supply” of ecosystem services from ecosystem assets owned by different economic units and “used” by other economic units / beneficiaries. Key insights from the information compiled in the supply and use account are:

- There are significant estimated benefits provided to households (worth at least $180 million a year, with an alternative estimate suggesting it could be worth at least $1.6 billion a year with the combined estimates of amenity and global climate regulation), government (approximately $115 million a year) and industry (approximately $20 million a year).
- Households directly benefit from air filtration, global climate regulation, local climate regulation and recreation (welfare and avoided health costs), food (market price) and amenity (property premiums). Government directly benefits from local climate regulation and recreation (avoided health costs). Industry directly benefits from local climate regulation (avoided health costs), food and recreation (productivity gains and GVA) and education (expenditure / GVA). (There are also indirect benefits of these ecosystem services that flow across these “users”).

The uncertainty ratings (scale of 1 (low) to 9 (high)) are shown as a guide for future work to refine the analysis that’s been undertaken for this initial urban Melbourne EEA and improve its robustness for decision making. The remainder of this concluding section sets out suggested next steps to refine and expand the urban Melbourne EEA in order to further its practical use to inform decision making within the region.

Table S1. Headline extent account for urban Melbourne EEA in 2019

	Urban asset type	Narrow urban asset type	Estimate	Metric	Uncertainty
Urban asset extent	Marine		0	Hectares	Medium
	Alpine		0		
	Shrubland		1,756		
	Grassland		15,799		
	Forest / woodland		13,870		
	Coastal margins		89		
	Farmland		5,749		
	Freshwater and wetland		2,794		
	Urban	Built-up areas	126,599		
		Integrated green infrastructure	15,829		
		Highly managed assets	31,892		
	Total		**214,378**		

Figure S2. Spatial distribution of ecosystem assets across the urban Melbourne EEA in 2019 (DELWP, 2020)

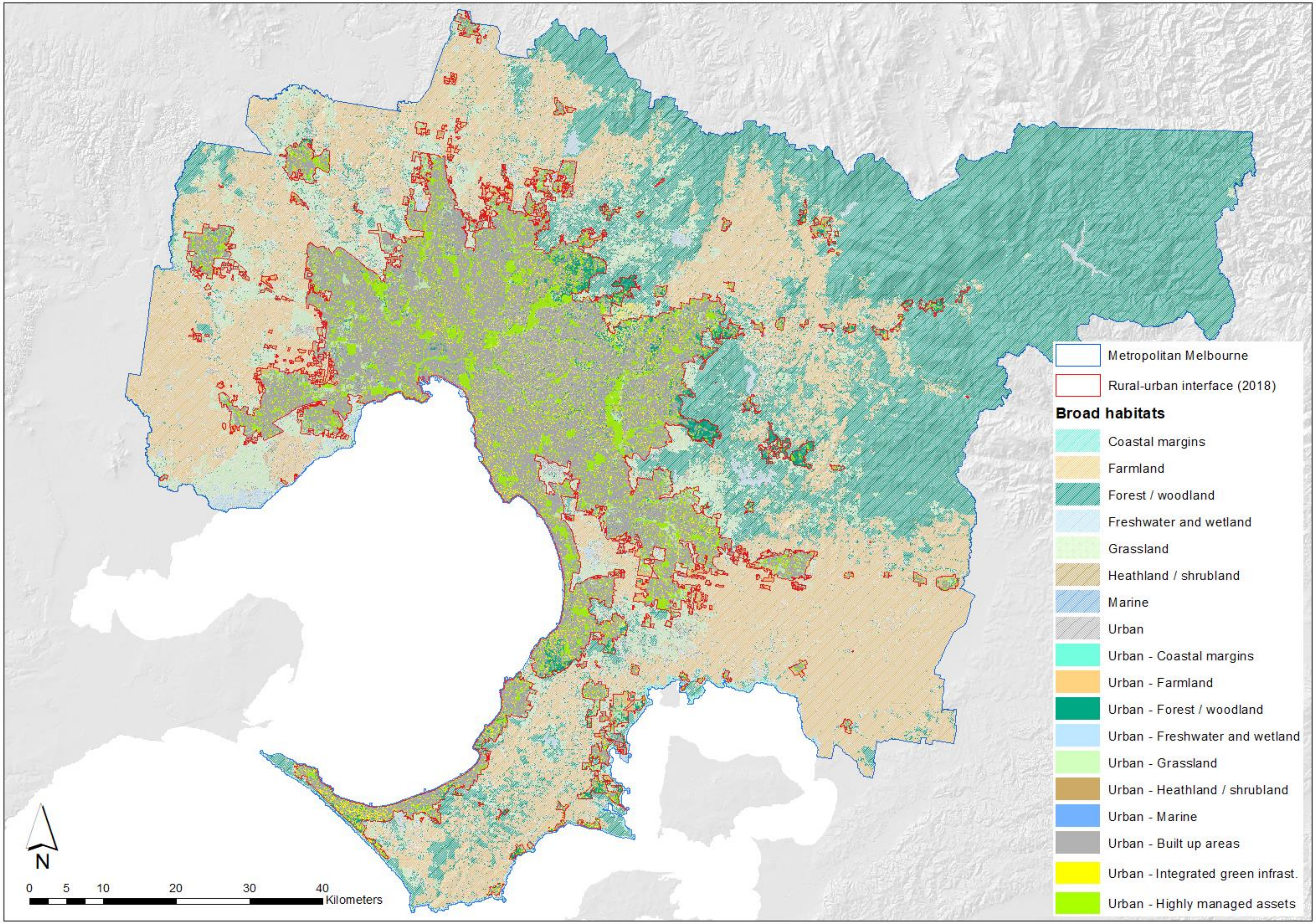

Table S2. Headline condition account for the urban Melbourne EEA

Condition category / Indicator	Ecosystem	Primary ecosystem service being supported	Resolution	Source	Year	Metric	Condition Score Urban Melbourne EEA area	Uncertainty
Ecological condition - Biodiversity								
Native vegetation condition	Terrestrial	Existence / option value	75m grid	DELWP (2017)	2017	Score 1 -100	8	Medium
Habitat importance-threatened species	Terrestrial	Existence / option value	225m grid	DELWP (2016a)	2016	Score 1-100	24	Medium
Threatened flora	Terrestrial	Existence / option value	Point data	DELWP (2021)	2021	Species count	111	Medium
Threatened fauna	Terrestrial	Existence / option value	Point data	DELWP (2021)	2021	Species count	103	Medium
Vegetation cover	Terrestrial	Existence / option value	1:5k	DELWP (2019a)	2018	% grass	16	Medium
						% shrub	6	Medium
						% tree	14	Medium
Vegetation biomass[a]	Terrestrial	Timber/Global Climate Reg	30m grid	DELWP (2018b)	2017	Tonnes/Ha	167	Low
Apiary Sites on public land	Terrestrial	Food	Point data	DELWP (2021a)	2021	Count	1	Low
Ecological condition – Soil								
Coastal acid sulphate soil susceptibility	Any / All	Saltwater ecosystem services	1:100k	DJPR (2003)	2003	Ha	9,691	Medium
Post fire landslide susceptibility	Terrestrial	Erosion regulation	1:25k	DELWP (2016b)	2010	Ha	1	Medium
Landslide susceptibility	Terrestrial	Erosion regulation	1:250k	DJPR & A.Miner (2017)	2017	Ha (high and v.high)	2,474	Medium
Ecological condition - Water								
Stream condition (index)	Streams	Freshwater ecosystem services	1:25k	DELWP (2010)	2010	Score 0-50	6 (very poor)	Medium
Estuary condition (index)	Estuaries	Freshwater ecosystem services	1:25k	DELWP (2021b)	2021	Score 0-50	23 (poor)	Medium
Retarding basins	Terrestrial	Flood regulation	1:5k	Melbourne Water (2019)	2021	Ha	986	Low
						Count	213	Low
Ecological condition – Carbon								
Carbon stock	All	Global climate regulation	100m grid	DISER (2021)	2019	tCO^2	5,555,655	Medium
						tCO^2 / Ha	26	Medium
						tCO^2e	20,355,921	Medium
Socio-economic characteristics – Location								
Light pollution	All	Aesthetics / Recreation	350m grid	Stare (2021)	2019	Radiance	16	Low
Proximity to open space	All	Recreation	1:5k	AUO (2020)	2018	% of dwellings within 400m of public open space	57	Low
Socio-economic characteristics - Cultural assets								
Historic cultural heritage (partly or wholly within open space)	Terrestrial	Existence / Recreation	Point data	DELWP (2019c)	2019	Ha	4,026	Low
						Count	907	Low
Socio-economic characteristics - Governance and management								
Designated water supply catchment	All	Water purification	1:25k	DELWP (2018c)	2021	Ha	73	Low
						Number	3	
Ramsar Wetlands	Wetlands	Habitat provision	1:25k	DEE (2017)	2021	Ha	204	Low
						Number	3	
National parks and nature reserves	All	Various	1:25k	DELWP (2021c)	2021	Ha	601	Low
						Number	26	
Other conservation reserves	All	Various	1:25k	DELWP (2021c)	2021	Ha	3,017	Low
						Number	139	

Condition category / Indicator	Ecosystem	Primary ecosystem service being supported	Resolution	Source	Year	Metric	Condition Score Urban Melbourne EEA area	Uncertainty
Socio-economic characteristics - Built assets								
Piers and jetties	Marine	Recreation and Tourism	Point data	DELWP (2020)	2020	Count	35	Low
Boat access points	Marine	Recreation and Tourism	Point data	DELWP (2020)	2021	Count	101	Low
Boating restriction zones[b]	Marine	Recreation and Tourism	1:25k	DELWP (2020)	2021	Ha	3,659	Low
Walking tracks	Terrestrial	Recreation and Tourism	1:25k	DELWP (2021d)	2020	Km	894	Low
Bicycle path	Terrestrial	Recreation and Tourism	1:25k	DELWP (2021d)	2020	Km	1,107	Low

[a] Above ground biomass data available on public land only.
[b] Boating and swimming zones are prepared under the Marine Safety Act 2010 with the primary aim of providing a safe environment for recreational water users.

Table S3. Summary flow (physical and monetary) accounts for urban Melbourne EEA in 2019 with uncertainty assessment

Ecosystem service		Scope	Physical flow			Monetary flow *(present value, 2021 prices)*			
			Estimate	Metric	Uncertainty	Estimate	Metric	Valuation approach	Uncertainty
Air filtration		Urban trees	1,500	Tonnes pollutants/yr	High	$6m to $6.4m	$m/yr	Damage costs	High
Amenity		Metropolitan and sports and rec. parks	-	-	-	$1,560m [b]	$m/yr	Hedonic price	High
Education		All ecosystems	295,000	Visitors/yr	Medium	$3.4m	$m/yr	Expenditure	High
Biomass for food	Agriculture	Farmland	48,000	Tonnes/yr	High	$8.7m	$m/yr	Resource rent from market prices [a]	High
			155,000	Livestock/yr					
	Community production	Community gardens	48,000	Kg/yr	High	$0.06m	$m/yr	Resource rent from market prices [a]	High
Global climate regulation	Carbon retention	All ecosystems	20.4m	tCO2e	Medium	$35m to $106m	$m/yr	Carbon price to social cost of carbon	High
	Carbon sequestration	*4 broad ecosystems/30% Urban Melb EEA area*	*150,000*	*tCO2e/yr*	*Medium*	*$6m to $19m*	*$m/yr*	*Carbon price to social cost of carbon*	*High*
Local climate regulation		*4 broad ecosystems/30% Urban Melb EEA area*	33	Additional mortality/yr	High	$173m	$m/yr	GVA contribution, welfare and avoided costs	High
			153	Additional morbidity/yr					
Recreation		Some parks, gardens and piers	7.2m	Visitors/yr	High	$91m	$m/yr	GVA contribution, welfare and avoided costs	High

[a] The contribution of the ecosystem to these socio-economic benefits is isolated at the monetary valuation stage in what is known as a "resource rent" calculation which strips out the contribution of other inputs (e.g., cost of human labour, machines etc) from the market price of the good / service.
[b] This is a not additive to other ecosystem services apart from global climate regulation. To do so would result in double counting.

Table S4. Summary supply and use account

Metric		Ecosystem service	Household	Government	Industry	Ecosystems
Supply	$ AUD / yr (2021)	Air filtration				$6m - $6.4m
		Education				$3.4m
		Biomass for food				$9m
		Global climate regulation				$35m - $106m
		Local climate regulation				$173m
		Recreation				$91m
		Total				**$317m - $389m**
		Amenity				*$1,560m*
Use	$ AUD / yr (2021)	Air filtration	$6m - $6.4m			
		Education			$3.4m	
		Biomass for food	$0.06m		$9m	
		Global climate regulation	$35m - $106m			
		Local climate regulation	$54m	$114m	$5m	
		Recreation	$86m	$0.5m	$4m	
		Total	**$181m - $252m**	**$115m**	**$21m**	
		Amenity	*$1,560m*			

This initial, proof-of-concept urban account for Melbourne will be a useful contribution to the potential development of Victoria-wide environmental-environmental-economic accounts for urban areas. The information compiled in the urban Melbourne EEA can be used:

a) As evidence of the total value of urban Melbourne’s ecosystem assets to the Victorian, Australian and global economy and community and the distribution of this across the region. The analysis undertaken for the urban Melbourne EEA suggests that the ecosystems of the region deliver ecosystem services that are worth at least $300 million per year, with an alternative estimate suggesting that the ecosystem services could be worth at least $1.6 billion per year.

b) To build the business case for investment and/or alternative policies/management to maintain current ecosystem status and productivity. The sustained delivery of the estimated annual benefits from urban ecosystems is dependent on current ecosystem status to be maintained (at a minimum). The distribution of socio-economic value is mapped (for most ecosystem services) across the region, enabling the identification of hotspots that deliver significant value to society that could provide some prioritisation of ecosystem maintenance.

c) To assess the effectiveness of existing policy and environmental management and identify opportunities to enhance ecosystem status and productivity through future policy/management/investment. Information on the current status and productivity of ecosystems in the urban Melbourne region can be judged against policy/management targets and where performance is poor this is suggestive of the need for improvement. For example, the urban Melbourne EEA condition account suggests that the status of native vegetation (8 out of

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100) and freshwater/estuaries (6 out of 50 and 23 out of 50 respectively) could be an area for improvement which could deliver enhancements in ecosystem service delivery (i.e. improved recreational experience, greater carbon sequestration etc).

d) To improve understanding of the trade-offs in the use of contested assets (e.g. between the use of ecosystem assets for recreation or biodiversity) and land use change (e.g. loss of ecosystems for built development). The information in the urban Melbourne EEA can be used to estimate what will be lost if the current ecosystems in the region are degraded / destroyed.

e) As a basis for collaborative working with land / water management organisations by using the accounts to explore synergies across ecosystems / geographic areas. This includes impacts and dependencies of assets under the Authority's management with other ecosystems / geographic areas. For example, the reliance of waterbody quality within urban Melbourne on land use outside of urban Melbourne area (and vice-versa).

f) As an underpinning evidence base to explore other policy and/or management issues including links to other reporting frameworks such as the Sustainable Development Goals, making the case for investing to expand ecosystem assets and estimating the magnitude and value of the loss of ecosystem service associated with pressures and risks.

g) As a useful contribution to the potential development of Victoria-wide environmental-environmental-economic accounts for urban areas.

Key recommendations for future work include:

- Refine the land cover extent information, using more highly resolute datasets including (potentially) Earth Observation data / the work being undertaken by Geoscience Australia (an Australian Government agency) to develop national land cover datasets utilising the FAO of the UN Land Cover Classification System.

- Further scientific and economic work should be done to explore "critical natural capital (ecosystem) asset characteristics" that are critical to supporting the provision of a specific ecosystem service of interest, such that if these characteristics were to decline, the capacity of urban Melbourne ecosystem assets to produce this ecosystem service declines substantially and (in some cases) abruptly and (potentially) irreversibly where threshold effects exist (Mace, 2019).

- Refine the analytical approach to estimating the physical and monetary estimates including:

    - Explore more refined methods to estimate the air quality regulating service of ecosystem assets, including those which calculate health benefits directly from the change in pollutant concentrations (i.e. exposure) rather than from tonnes of pollutant removed.

    - Explore how amenity values vary according to a broader range of ecosystem asset types and the quality of ecosystem assets and park facilities (e.g. walking paths, bridleways, benches, toilets, playgrounds etc.) which contribute to determining people's enjoyment / welfare and physical and mental health benefits.

    - Explore ways to capture the true economic value of educational visits.

    - Explore other potential socio-economic benefits of food production beyond the economic value of food production.

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- Expand the coverage of carbon sequestration beyond the two broad ecosystems (inland wetlands and forests) and two narrow ecosystem assets (trees and parks) currently assessed.

- Refine approach to estimating local climate regulation by developing locally specific estimates of urban cooling by all ecosystem assets in a locality.

- Explore using mobile phone data and/or access movement data to quantitatively monitor recreational visitation activity.

- Seek to estimate the type of nature based activity being undertaken in the urban Melbourne EEA region.

- Refine assumption of 20 percent market value being estimated resource rent for market goods (where this has been adopted in the absence of information).

- Consider using bio-physical models (e.g., InVEST) to explore confidence in estimates and / or expand coverage of ecosystem services assessed.

• Expanding / integrating the urban Melbourne EEA with other information to broaden the use of the account in the following ways:

  - Explore estimating physical and monetary values of ecosystem services that were scoped out of this initial urban Melbourne EEA including noise attenuation, flood risk regulation, water provision and water purification.

  - Applying historical data to the framework that has been developed for urban Melbourne EEA to enable changes in ecosystem status and productivity to be understood over time by comparing with the urban Melbourne EEA for 2019. The "historical" period(s) adopted will depend primarily on data available.

  - Applying projections of key variables (population, climate change etc.) to estimate the future magnitude and value of ecosystem services into the future as a capitalised value of ecosystem stocks (like the value of a house), rather than the annual value at a point in time (like the rent paid on a rental property) which can be useful in demonstrating the value of ecosystems over the long term.

  - Consider integration of the urban Melbourne EEA information with other information to report on the Sustainable Development Goals (SDGs) which are a collection of 17 interlinked global goals designed to be a "blueprint to achieve a better and more sustainable future for all".

  - To build the business case for investment to expand ecosystem assets within the urban Melbourne EEA. The underlying data and analysis that is used to build the urban Melbourne EEA could be applied to estimate the physical and monetary value of prospective changes in ecosystem extent that might be delivered through future policy/management/investment. For example, options to restore historical ecosystem extent within the urban Melbourne EEA could be assessed and estimates of the type, magnitude and value of ecosystem service provision could be developed to inform decision making.

  - To assess the magnitude and value of the loss of ecosystem service associated with pressures and risks in the urban Melbourne EEA region. Key pressures on urban ecosystems globally are population change; climate change induced sea level rise and temperature change; tree removal; urban development and wildfire.

1. Introduction

1.1. Background

The value of green and blue infrastructure in urban environments is well established and widely acknowledged. Urban parks, market gardens, street trees, rivers and lakes provide food and recreational opportunities, as well as regulate noise, air quality and local and global climates. These environmental goods and services lead to a range of health and wellbeing benefits, as well as financial benefits, that can be quantified and valued using economic analysis.

There is a significant amount of data and analysis on the socio-economic value of green and blue infrastructure in Victoria and Melbourne, however it is not currently consolidated or articulated in a way that is useful for decision makers. Addressing this evidence gap by developing an Urban Melbourne environmental-economic account was supported by DELWP’s green infrastructure working group and received sign-off from DELWP’s Senior Leadership Team in 2019.

1.2. Study objectives

This project develops a baseline environmental-economic account for urban Melbourne that aligns with the UN System of Environmental Economic Accounts – Ecosystem Accounts guidance (UN, 2021). The UN SEEA is a framework for reporting on links between the environment and the economy using internationally agreed accounting concepts.

The methodological approach to urban Melbourne EEA development was agreed with the project steering group (DELWP’s green infrastructure working group) based on a review of economic assessments of urban ecosystem assets globally, international guidance on environmental-economic accounting as well as existing information on ecosystem status and productivity within Melbourne and the study teams’ experience in developing environmental-economic accounts (see Annex 1 for further information on the scoping phase of this project).

The baseline account will report the current status of urban ecosystem assets (including urban rivers and urban woodland as well as street trees, green roofs, parks etc. that are integrated into built-up areas) within the region and the importance of these assets in supporting health, wellbeing and livelihoods. The information compiled in this environmental-economic account could be used by decision makers in the following ways (note that some of these require additional analysis / data to be combined with baseline accounting information, including accounts being developed for historical periods or future scenarios):

- As evidence of the value of Melbourne’s urban ecosystems to the Victorian, Australian and global economy and community.
- To assess the effectiveness of existing policy and environmental management.
- To identify investment opportunities and/or alternative management to improve economic / community outcomes.
- To improve understanding of the trade-offs in the use of contested assets (e.g. between the use of ecosystem assets for recreation or biodiversity) and land use change (e.g. loss of ecosystems for built development).
- To build business cases for future government interventions (investment or policy interventions) to protect, restore or expand urban ecosystem assets within Melbourne in order to sustain economic and social prosperity.
- For reporting purposes including potentially linking to the Sustainable Development Goals (SDGs) in the future.
- To assess the implications of key risks associated with pressures (e.g. climate change, urban development) and consider the implications of these for the economy and community.

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2. Scope

2.1. Overview of environmental-economic accounting

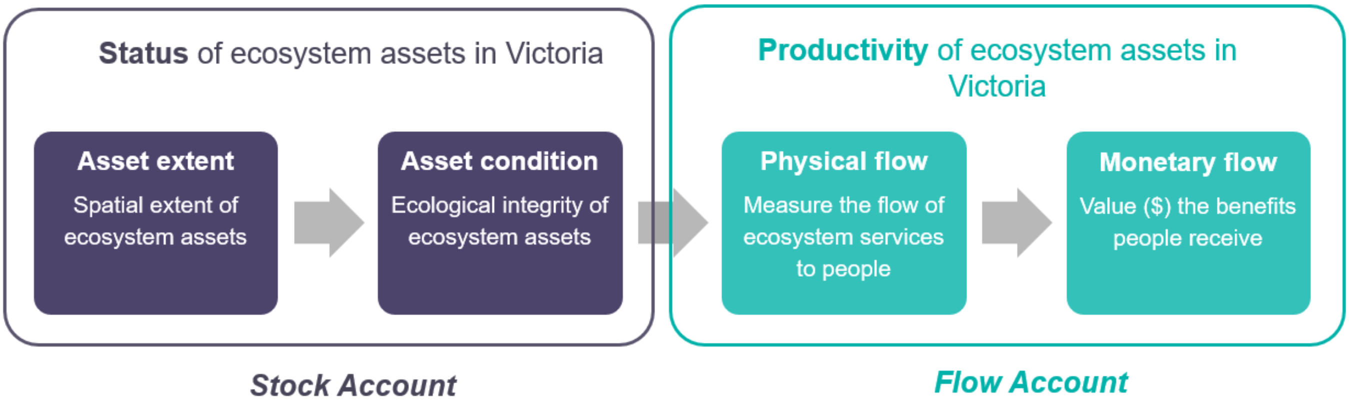
Environmental-economic accounting (EEA) gained momentum following the recommendations of the 1992 Rio "Earth Summit"[1], which recognised the need for more holistic indicators of society's development beyond economic output (i.e. Gross Domestic Product - GDP) to include broader social and environmental indicators. The intention is to ensure economic growth and societal prosperity can be sustained into the future by recognising the status of the underlying stock of environmental assets on which the economy and society depends (acknowledging the costs of economy growth such as pollution, habitat loss etc.). It specifically recommended that countries implement environmental-economic accounts at the earliest date.

In response, the United Nations Statistical Division (UNSD) published guidance on integrated environmental and economic accounting (UN, 1993; UN, 2003; UN, 2012; UN, 2021) and the latest (2021) version was adopted as the international standard for organising information on the environment and its contribution to economic and other human activity. The UN System of Environmental-Economic Accounting (SEEA) framework is consistent with the international standard of System of National Accounts (i.e. GDP) in order to report on the interactions between the economy and the environment at the national level, most often as "satellite accounts" to national GDP accounts.

Governments around the world, including Australian Commonwealth, state and territory governments, have begun developing and implementing EEA to inform public policy development. Australia has a national strategy to deliver a common national approach to environmental-economic accounting based on the UN SEEA that was endorsed by Commonwealth, state and territory environment ministers in 2018.

Ecosystem accounts are a type of EEA that take stock of current ecosystem assets – in terms of their extent, location, and condition – and quantify and value the flow of ecosystem services that these assets generate for people, who enjoy benefits from them. Figure 2.1.1. sets out the ecosystem accounting framework.

Figure 2.1.1. Environmental-economic accounts - ecosystem accounting framework



Ecosystem accounts consist of several linked sub-accounts (see Figure 2.1.1.), which will be developed as follows for urban Melbourne:

[1] The recommendations of the UN Conference on Environment and Development in Rio are set out in Agenda 21. This is a non-binding action plan of the United Nations with regard to sustainable development.

- Ecosystem asset extent account: this account reports information on the extent (e.g. hectares) of ecosystem assets within the study area. The precise definition/classification of broad ecosystems is based on an agreed systematic classification/typology of environmental assets (e.g. habitats) in Victoria / Australia from the literature and includes marine, alpine, shrubland, grassland, forests / woodland, coastal margins, farmland, freshwaters and wetlands and urban. In the absence of an agreed classification for more specific ("narrow") urban ecosystem assets / features, an indicative set of green-blue infrastructure features (such as street trees, green roofs and road verges) is identified from the literature and information will be compiled on these features based on data available for urban Melbourne.

- Ecosystem asset condition account: this account compiles information on a range of metrics which capture the ecological condition and socio-economic characteristics of urban ecosystem assets within the study area. The specific metrics reported depend primarily on the availability of information, with consideration also given to what is useful to understand from a policy / management perspective and scientific and economic understanding of the importance of that metric in determining the capacity of the urban ecosystem asset stocks to support ecosystem service flows.

- Physical account of ecosystem service flows: this account quantifies the physical provision of ecosystem services over time based on an agreed systematic classification/typology of ecosystem services from the literature (the Common International Classification of Ecosystem Services; EEA, 2019). Metrics for quantifying different ecosystem services include visit numbers (for recreation and education), tonnes of carbon sequestered (climate regulation), kilograms of crops produced (food provision).

- Monetary account of ecosystem service flows: this account values ($) the physical provision of different ecosystem services over time using different economic valuation techniques ranging from people's willingness to pay (which is a welfare value) to resource rent based on actual market transactions (exchange values, based on the amount actually paid minus the cost of other (non-natural) inputs to production).

  The interactions between the economy and the environment are reported on in environmental-economic accounts by isolating the contribution of the environment to goods and services that are captured in conventional economic (GDP) accounts. However, the accounting framework also extends to include the broader ("non-market"/public good) values that are supported by the environment (and delivered by government), but which are not captured within GDP accounts. This broader framing of value provides decision makers with an understanding of the total societal value provided by the natural environment, not just its contribution to supporting tourism, agriculture, fishing and forestry (for example).

- Supply and use tables: In addition to the stock and flow accounts, the SEEA guidance recommends reporting the "economic unit" and "ecosystem type" that is supplying and using ecosystem services. Understanding the extent to which ecosystems services are "supplied" from different ecosystem assets (which are owned/managed by different economic units) and "used" by economic units / beneficiaries (i.e. business, household, government) is important from a management perspective as it can facilitate strategic collaborative approaches to natural resource management and can contribute to developing alternative funding models.

2.2. Alignment of Urban Melbourne EEA with SEEA-EA

The environmental-economic account developed for urban Melbourne will align with existing environmental-economic accounts within Australia and internationally. The urban Melbourne EEA will adhere to the SEEA-EA standard as an example of a "thematic account" in which the environmental-economic account is combined with other data, evidence and analysis that can be structured and integrated following accounting principles to support broader analysis and provide a coherent information set to support policy decisions (UN, 2020). Key areas where the urban Melbourne EEA will diverge from the stringent accounting requirements and standardisation of the forthcoming SEEA-EA statistical standard as follows:

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- **Spatial framing**: the account adheres to the strong spatial framing that is encouraged under the SEEA-EA statistical standard as far as possible / practical but will include non-spatially disaggregated (top-down) information where appropriate and useful for informing policy (potentially the case for flow accounts where data limitations mean mapping provision spatially is not appropriate if robustness / accuracy is to be maintained).

- **Condition account**: The metrics within the ecosystem condition account capture ecological integrity as per SEEA-EA guidance but extend beyond this to also capture other variables that are necessary to co-produce ecosystem services from ecosystem assets (Dickie et al, 2014). Including these broader metrics is important from a policy/management perspective as it provides for an understanding of the underlying drivers of differences in ecosystem service provision across space (and time if these metrics / the account is developed for different time periods) and to consider how opportunities to boost ecosystem service provision can be delivered in a way that does not reduce ecological integrity and/or provides for net gains in societal welfare (e.g. the proximity of green space to urban residents is important in determining the amenity and recreational value it provides).

- **Assessment year:** The urban Melbourne EEA has been developed for 2019 on the basis that this is the most recent year for which most of the necessary information exists (including the latest ecosystem extent data in Victoria). Information for 2019 has been used where possible and where 2019 data is not available it is taken from the years 2015 to 2021 (some condition data precedes this but is presented for completeness). The account could therefore be more accurately described as being representative of ecosystem status and productivity over the period 2015 to 2021. Whilst it is understood that presenting data across a range of years is not good accounting practice, the primary aim for the urban Melbourne account is not to produce statistics (as developed by statistical agencies for national accounts) but rather to inform policy development. This means that a more pragmatic approach is being taken compared to the accounting / statistical rigour and standardisation required by SEEA-EA. To limit the scope of accounts to where data can be provided for a given year could limit the scope of the account and therefore its use for informing policy decisions.

  Where it is necessary to select a specific year (within the 2015-2020 period) to align multiple datasets, assumptions are made to combine data from multiple years in a way that relates to 2019, with the year of the underlying source and data being made clear. This is mainly relevant for the ecosystem service flow accounts which will be developed for 2019 on the basis that this is the year of the underlying ecosystem extent data and because this does not skew the value of ecosystem services (specifically recreation and education) due to the effect of COVID-19.[2]

- **Exchange and welfare values:** in order to satisfy the requirements of the SEEA-EEA and also be useful for informing government decision-making, the urban Melbourne EEA develops estimates of exchange values (in order to develop SEEA-EA compliant environmental-economic account) alongside welfare values (for informing policy decisions).

- **Policy issues**: the study team has considered if / how the urban Melbourne EEA could be expanded in line with the SEEA framework in the future, to include broader information of interest to policy decision makers. This includes information related to historical changes, future changes, negative pressures, positive dependencies, links to Sustainable Development Goals and business case / investment opportunities.

[2] For example, ecosystem service estimates rely on extent data from 2019 as well as estimates of the relationship between ecosystem extent and its productivity which may be from academic research undertaken in 2015. Therefore, an assumption is adopted that this relationship is stable and relevant to apply to an analysis that is being developed for 2019.

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2.3. Defining the environmental-economic accounting area and urban ecosystem assets

The environmental-economic accounting area is the geographical area for which an environmental-economic account is compiled. Within the geographic boundary set by the environmental-economic accounting area there may be many different ecosystem asset types, of which urban ecosystem assets may be one.[3] Therefore, the geographic boundary does not (necessarily) define the urban ecosystem area to be assessed, but rather defines the boundary of the land area to be assessed.

Many of the urban ecosystem boundaries that are defined in the literature conflate the environmental-economic accounting area (i.e. geographic boundary of an account) with the definition of urban ecosystem assets (see Annex 2 and 3 and footnote[4]). For example, by setting the environmental-economic accounting area for the urban Melbourne account as metropolitan Melbourne and assuming all ecosystems within that area are urban ecosystems. This approach is appropriate where the objective is only to develop an urban environmental-economic account for a specific geographic area at a point in time. However, this approach does not define a rule for consistently establishing urban ecosystem assets within the landscape. Therefore, this approach will not enable understanding of land use change / urban development over time (i.e. where accounts are developed over time) or facilitate the development of a comprehensive and integrated set of environmental-economic accounts for an entire State or country.

For the purpose of developing this Urban Melbourne environmental-economic account, the geographic boundary and definition of urban ecosystem assets are assumed to be the same. The boundary is set by the rural-urban interface and all areas within the interface boundary are considered to be urban, see Figure 2.3.1. This simplified approach was deemed to be appropriate because the interface is an outer boundary of the urban area in Melbourne and captures ecosystem assets that are typically understood to be urban (pers. comm. DELWP Planning), it is also the most recent (2018) information on urban extent at high resolution. Whilst small pockets of urban areas do exist within the broader metropolitan Melbourne region, these are considered “peri-urban” rather than urban (pers. comm. DELWP Planning).

[3] Ecosystem assets in SEEA-EA (2021) are the primary units for environmental-economic accounting. The environmental-economic accounting area provides the accounting boundary around a set of ecosystem assets, such that the sum of the ecosystem assets is equal to the total area delineated by the environmental-economic accounting area. Ecosystem assets are contiguous spaces of a specific ecosystem type characterised by a distinct set of biotic and abiotic components and their interactions.
[4] For example, The European Commission’s Mapping and Assessment of Ecosystem Services (MAES) 4th Report notes that for mapping and assessment of urban ecosystems and their services, the boundary of an urban ecosystem “depends on the policy questions of the assessment, the scale of the different socio-ecological processes, and the indicators and data available for the assessment.” SEEA (UN SEEA, 2019) also notes that the boundary should be set so that usefulness of urban accounts is optimised, and that there are many different ways in which the outer boundary can be defined: “For example, depending on the purpose, urban areas may be defined based on administrative boundaries, population, population density or functional characteristics defined for example by commuting flows or a specific ecosystem function, morphological criteria such as built-up extent and others.”

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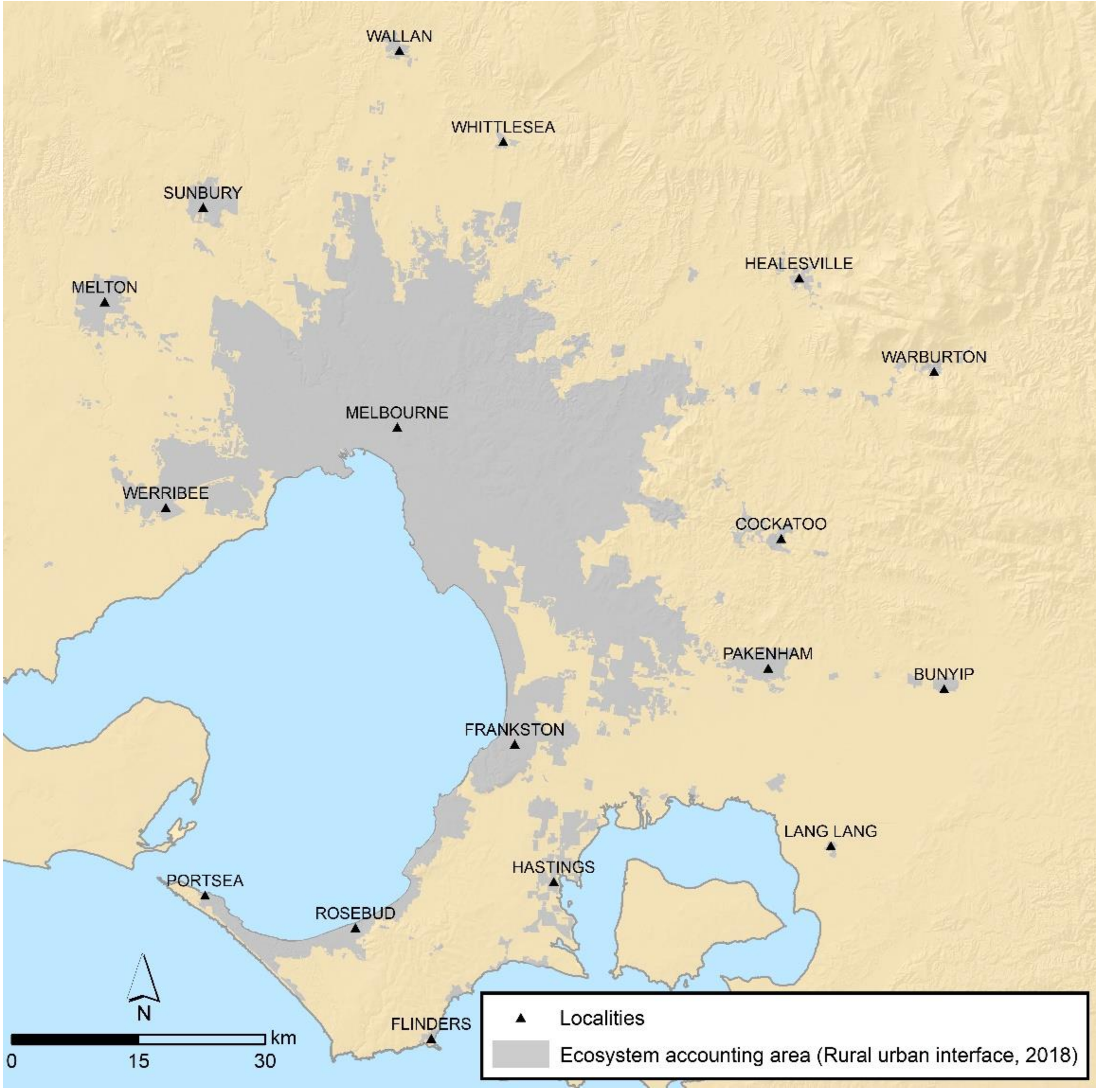
Figure 2.3.1. Environmental-economic accounting area for the Urban Melbourne environmental-economic account



The scope of ecosystem assets that are included within this urban Melbourne account are those that are actually situated within the urban fabric (i.e. within the rural-urban interface area). The study is therefore interested in the contribution of ecosystem assets *located in* urban areas to society's consumption of ecosystem services and benefits (i.e. including people who are situated within and potentially outside of urban areas). This is not to be confused with a possible alternative approach that includes *all* assets that deliver ecosystem services / benefits to the urban population. The study will also therefore not capture the relative contribution of urban ecosystem assets to Melbourne residents' use of ecosystem services (as the total use of ecosystem services is needed to get this result).

Furthermore, the study will not consider the "import" and "export" of ecosystem services across the geographic boundary of the account. For example, food produced within Melbourne (which will be captured within the account) might not be consumed within Melbourne, but "exported" and consumed elsewhere. Similarly, food consumption by Melburnians will embody ecosystem services that have been "imported" following production elsewhere (which will not be captured within this account).

In order to address the issue of scaling accounts (i.e. developing urban environmental-economic accounts at different scales) and to contribute to the potential future development of a comprehensive and integrated set of environmental-economic accounts for the State of Victoria, consideration is given to the approach that should be adopted to defining urban ecosystem assets across the State. This requires a rule that can consistently applied to define urban ecosystem assets separate to other types of ecosystem assets (such as forests, freshwaters, farmland etc), see Box 2.3.1.

Box 2.3.1. Potential approach to defining ecosystem assets for comprehensive accounts across Victoria

Urban ecosystems are one of nine broad ecosystem types that have been classified by the study team for the purposes of developing mutually exclusive environmental-economic accounts within Victoria, as follows:

1. Marine
2. Alpine
3. Shrubland
4. Grassland
5. Forest/woodland
6. Coastal margins
7. Farmland
8. Freshwater and wetland
9. Urban

Operationalising the above ecosystem classification requires these broad ecosystems to be defined using spatial data in Geographical Information Systems (GIS) that can track changes in the area of these ecosystem assets over time (e.g. through land use / cover change).

Low resolution datasets such as the Victorian Land Cover Time Series (see Annex 4) are potentially suitable for developing ecosystem extent accounts for broad ecosystems at regional/State/national level (i.e. the VLCTS is low resolution at 25 metres). Whilst the VLCTS can provide a breakdown of the broad ecosystem types, it is not sufficient for defining “urban” ecosystem assets which include urban forests, coastal margins, freshwaters (i.e. some of the other broad ecosystem assets need re-defining as urban).

In future, if an urban account is to be developed for Victoria as a whole, it is recommended that the broad ecosystem assets that are part of the urban fabric (i.e. ecosystem assets that are conventionally considered to be “urban” assets including urban forests, coastal margins, freshwaters etc.) are captured by developing an adjusted Place Area Polygon / Built-Up Area layer. This will require the application of a variable buffer to the built-up area (i.e. applied according to the size of the built-up area polygon so that smaller built-up areas, such as in regional Victoria, that are likely to be surrounded by ecosystem assets have a smaller buffer than larger built-up areas), as per the approach taken in the UK Urban Natural Accounts (eftec, 2017).

The use of an adjusted built-up area dataset (based on VicMap built-up area, see Figure 2.3.2.) is deemed to be the most appropriate dataset to use as a basis to distinguish urban ecosystems from non-urban ecosystems because this would:

a) Provide a consistent rule for defining “urban ecosystems” (including urban forests, freshwaters etc) at different scales (local / regional / State / national) at high resolution;
b) Cover the entire area of Victoria including in regional areas outside of Melbourne (i.e. beyond the rural-urban interface in Figure 2.3.1.), as shown in Figure 2.3.2.
c) Reflect urban development over time as it is based on high resolution data of built-up areas (rather than an administrative boundary that does not change with urbanisation).

If comprehensive environmental-economic accounts are developed for the entire geographic area of Victoria in the future, then trade-offs can be assessed between future urban expansion and losses of ecosystem services, which is useful for decision makers. (The current scope of the urban Melbourne environmental-economic account will not

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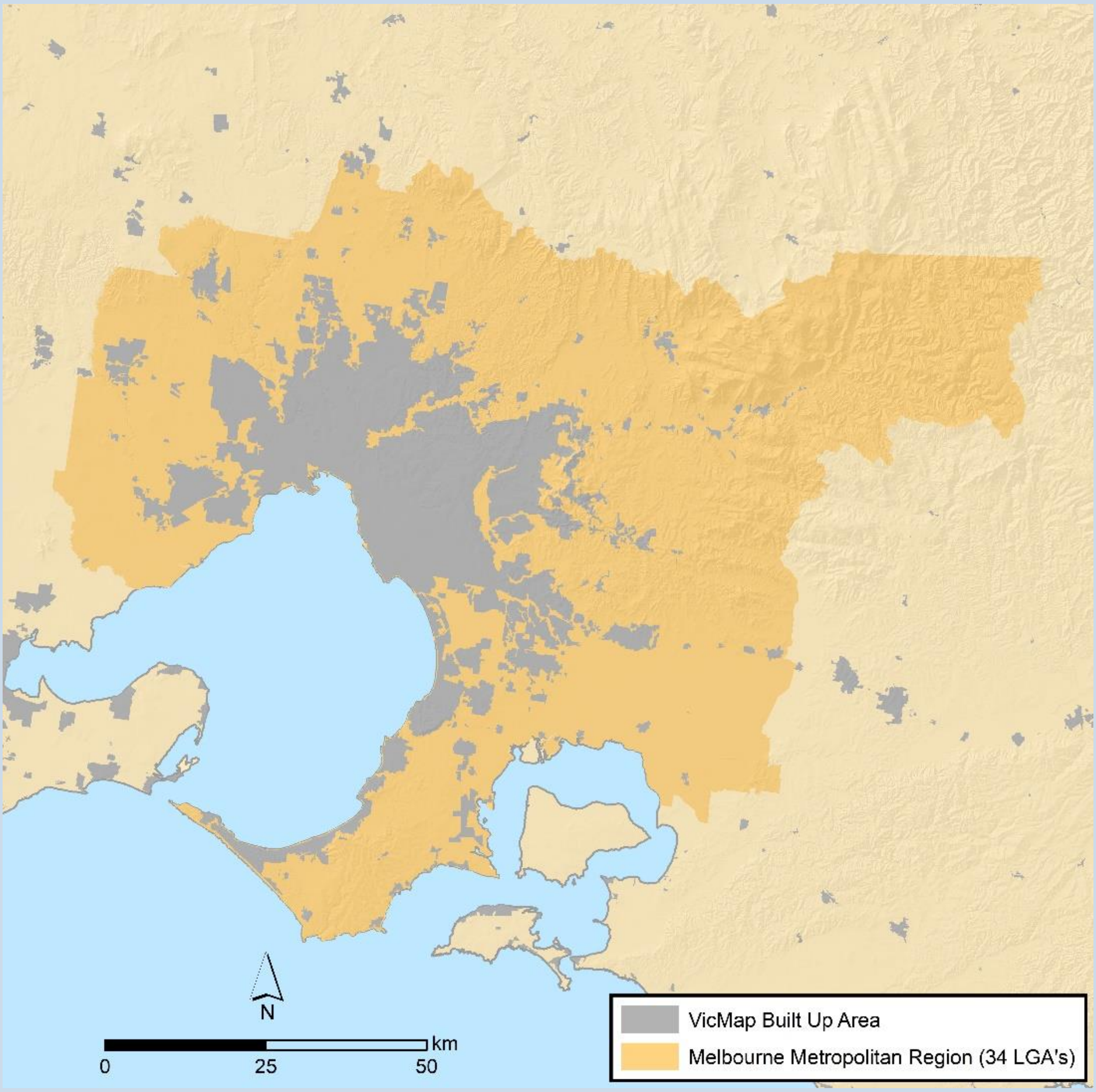
tell us about losses in ecosystem services as a result of urbanisation as ecosystem service provision is not quantified and valued for ecosystem assets in peri-urban and rural areas).

If future urban accounts were developed at State level and an adjusted built-up area dataset is adopted to define urban areas / ecosystems, some reconciliation would be required with the current urban Melbourne EEA given that the environmental-economic accounting area used for this account is the rural-urban interface and not the built-up area dataset.

Figure 2.3.2. Illustration of the VicMap Built-Up Area dataset for defining urban ecosystem assets in Victoria



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2.4. Socio-economic benefits within scope

The SEEA guidance (UN, 2012; 2021) recommends the use of an ecosystem service framing to link the ecological functioning of ecosystem assets to the socio-economic benefits enjoyed by society. The focus is on isolating and recording the ecosystems contribution, through flows of ecosystem services, to benefits[5] received (UN, 2020b). SEEA (UN, 2012) suggests the use of "logic chains" to explain the logic of these links, as was developed for in UK urban accounts (eftec, 2017) and other UK environmental-economic accounts (eftec, 2015; AECOM, 2015).

Annex 5 provides more detail on the scope of ecosystem services within the reviewed literature. Key conclusions from this review are that the urban Melbourne EEA will take the following approach:

- Comply with the Common International Classification of Ecosystem Services. Provisioning services will be measured through physical output, regulating services through reductions in environmental harm and cultural services through number of interactions.
- Focus only on biotic services and not include other flows from the environment, such as abiotic services.
- Focus on quantifying and valuing "final ecosystem services" as far as possible given the conceptual and practical challenges associated with valuing supporting services[6] in a way that avoids double counting.
- Supporting services such as biodiversity habitat will be captured as stock metrics in the asset extent and condition assessment.
- Where appropriate, an additional flow assessment will report "socio-economic" impacts which typically estimate the population affected by regulating services.

In the absence of an agreed classification of urban ecosystem services the study team has identified eleven ecosystem services as being potentially within scope of this initial urban Melbourne assessment, to be quantified and valued subject to data availability. These have been selected on the basis that these are the most commonly assessed in the reviewed literature and the most important final ecosystem services from a policy perspective within the Melbourne context:

1. Air filtration
2. Amenity (bundle of ecosystem services)
3. Education
4. Flood mitigation
5. Biomass provision - Food
6. Global climate regulation
7. Local climate regulation
8. Noise attenuation
9. Recreation: passive & active (health)
10. Water purification
11. Water supply

[5] Benefits are distinguished as being either SNA benefits (produced by economic units such as food, water, energy) or non-SNA benefits (not produced by economic units such as clean air, flood protection).
[6] Supporting services were originally defined in the Millennium Ecosystem Assessment as services that maintain the conditions for life on Earth and are thus necessary for the production of all other ecosystem services. Supporting services differ from final ecosystem services in that their impacts on people are either indirect or occur over a very long time (e.g. humans do not directly use soil formation services, although changes in this would indirectly affect people through the impact on the provisioning service of food production) (MA, 2005). These supporting services are treated as part of the underlying structures, process and functions that characterise ecosystems and since they are only indirectly consumed or used they may simultaneously facilitate many final ecosystem services (CICES, 2021).

A review of the data and methods that is available for the above eleven ecosystem services determined the final scope of ecosystem services to be included within the account and contributed to the identification of key evidence gaps to fill through future research. The quantification and monetisation of ecosystem services is only recommended in cases where data and methods are sufficient to produce estimates for the Melbourne area that have an acceptable level of certainty. Any set of environmental-economic accounts is only as good as the information and data used to populate it (VEAC, 2019).

Seven ecosystem services were selected for assessment in this initial urban Melbourne EEA on the basis that the data and methods available in the region are sufficient to enable ecosystem service quantification and valuation in the region (see Annex 5 for detail) (descriptions of ecosystem services align with SEEA-EEA (2020b):

1. Air filtration
2. Amenity: bundle of ecosystem services
3. Education
4. Biomass provision - Food
5. Global climate regulation
6. Local climate regulation
7. Recreation: passive and active (physical health)

There is some potential overlap across these seven ecosystem services which means that there is a possibility of different valuation estimates capturing (all or part of) the same value. These overlaps will be explained clearly and transparently in the Melbourne EEA outputs notes to ensure that no double counting of value occurs. (This is most evident for amenity valuation which captures a bundle of ecosystem services).

In addition, this report outlines how urban ecosystems in Melbourne provide the following ecosystem services and explores options for quantifying and valuing these:

- Cultural value
- Existence / Option value

Noise regulation and the three water based ecosystem services (flood mitigation, water supply and water purification) that were identified for potential inclusion within this initial Melbourne assessment are not quantified and valued as part of this initial Melbourne EEA. This is because the methods needed to estimate the physical and monetary provision of these services in a way that is useful for policy teams requires more advanced techniques (e.g. technical bio-physical modelling), some of which already exist on this within DELWP and / or would require further research / analysis. These ecosystem services are therefore suggested as areas for future research to expand the urban Melbourne EEA.

2.5. Practical and technical considerations

Based on the review of literature and study team experience in developing environmental-economic accounts, the urban Melbourne EEA will take the following approach to key practical and technical issues (see Annex 6 for more detail):

- Whilst the preference is to develop an urban Melbourne EEA with a strong spatial framing on which data of varying resolutions can be overlayed, constraints on the data and methods available could limit the extent to which this is feasible / proportionate for all sub-accounts. Therefore, the status and productive value of ecosystem assets within the assessment boundary will be reported at a resolution (e.g. $1km^2$, land cover polygon, local government area, broad habitat, metropolitan Melbourne area), type (qualitative, quantitative, monetary) and format (tabular or spatially explicit) that is feasible given data collection and is useful for decision making;

- The urban Melbourne EEA will report a single estimate of ecosystem service provision (i.e., *physical* provision) as opposed to a range, as per SEEA guidance. However, where possible and useful, a range of monetary valuation approaches (e.g., welfare and exchange values) will be taken and this range will be reported in the *monetary* account.

- Uncertainty will be summarised by using scores of 1 (low), 2 (medium) and 3 (high) for the robustness of (a) evidence sources and (b) methodological assumptions. These scores will be combined through multiplication to estimate an overall uncertainty score considering the confidence in the underlying data and key assumptions made, see Table 2.5.1. The overall (i.e. combined) uncertainty ratings and scores are as follows:

- Low uncertainty = 1 to 2 *(high confidence)*
- Medium uncertainty = 3 to 4 *(medium confidence)*
- High uncertainty = 6 to 9 *(low confidence)*

Table 2.5.1. Approach to assessing uncertainty

Assumptions (score)		Evidence (score)		
		Low (1)	Medium (2)	High (3)
	Low (1)	1	2	3
	Medium (2)	2	4	6
	High (3)	3	6	9

- Ecosystem service measurement baselines (also referred to as counterfactuals) are needed in environmental-economic accounting to ensure consistent quantification of ecosystem service flows in different contexts and are implicitly set at zero (i.e. no ecosystem service provided) (UN, 2020a). Environmental-economic accounts therefore report the "total" (not marginal) provision of ecosystem services by environmental assets. A "no ecosystem asset (natural capital)" baseline (i.e. concrete) is used in the urban Melbourne assessment because it is the only baseline to give us the total provision of ecosystem services of current ecosystem assets.

- The year for which an environmental-economic account is developed depends primarily on data availability. Information for 2019 has been used where possible and where 2019 data is not available it is taken from the years 2015 to 2021 (some condition data precedes this but is presented for completeness). Where it is necessary to combine datasets from multiple years to produce an estimate for the urban Melbourne EEA, assumptions are made to combine this information in a way that relates to a given year (i.e. 2019), although the year of the underlying source and data is still made clear. For example, estimates of the relationship between an ecosystem and its production of an ecosystem service may be from academic research undertaken in 2015 and an assumption is adopted that this relationship is stable and therefore relevant to apply to an analysis that is being developed for 2019. Economic valuation ($) information is drawn from multiple years and will be uprated for inflation to present value (2021) terms. Where capitalised values are used and an annual value is needed an equivalent annual cost calculation will be adopted using a 4 per cent discount rate over an appropriate time period (depending on the asset).

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3. Stock accounts

The ecosystem asset stock accounts report information on ecosystem extent and condition. Tracking changes in these metrics over time can be useful to inform decision making. For example, extent or condition metrics that are consistently tracking down (or up) might be a cause for concern (i.e. if this reflects a loss of extent or degradation) and warrant further investigation and potentially a policy and/or management response.

3.1. Ecosystem asset extent

3.1.1. Methodology

Once the environmental-economic accounting area and geographic scope of urban ecosystem assets are defined (see Section 2), it is necessary to classify urban ecosystem assets so they can be consistently organised within the environmental-economic accounting framework over time. There was no classification of urban ecosystem assets in the literature reviewed, see Annex 3. The classification of ecosystem assets for use in the urban Melbourne EEA is set out in Table 3.1.1. and:

a) Is based on a classification of broad ecosystem assets which is useful for analytical purposes because together these geographic areas sum to the total land area (e.g. of Victoria) and are mutually exclusive.[7] See Box A3.1. in Annex 3 for more information on the proposed classification of broad ecosystems for environmental-economic accounting in Victoria.

b) Breaks down the broad ecosystem assets into “urban” and “non-urban” ecosystems, with this delineation being based on whether these assets exist within or outside of the rural-urban interface. These land areas / water bodies could be classified under other (non-urban) broad ecosystem types but are relevant to consider in an “urban” account because of their proximity to high population densities in built-up areas (with potential reconciliation to wider environmental-economic accounts if they are developed to ensure no double counting). For example, rivers running through the city could be part of a freshwater environmental-economic account or an urban environmental-economic account.

   In practice, it is inconsequential whether a given land area is captured / assessed in another broad ecosystem (e.g. grassland) or an urban account (i.e. urban grassland) so long as a given land area / water body (and the associated bundle of ecosystem services produced) is not captured in multiple environmental-economic accounts for a given land area (e.g. where comprehensive and integrate accounts are developed for the State of Victoria) as this could risk double counting of value. This approach simply recognises the potential importance of the proximity of ecosystem assets to high density population (in urban areas) in determining their value (i.e. greater number of beneficiaries of cultural and regulating services). Implementing this in practice will require a rule on which to determine what land areas should be captured in urban environmental-economic accounts versus non-urban environmental-economic accounts (e.g. should a large relatively natural grassland area that is wholly surrounded by an urban area be included under a grassland or an urban account), see Annex 3 for the proposed rule to be applied if comprehensive and integrated environmental-economic accounts for Victoria are desired in the future.

[7] More specific definitions of habitats is provided in the UK approach in order to ensure mutual exclusivity across habitat types and this will also be required for Australia. For example, grassland is defined as “semi-natural grassland - all grasslands unimproved for agricultural purposes including a range of grassland types”. This is important to distinguish from agricultural grassland. Farmland is defined as “enclosed farmland - arable, horticultural land and improved grassland as well as associated boundary features e.g. hedgerows).

Unofficial

c) Breaks down the broad ecosystem classification of “urban ecosystems” to provide more insight into the productivity of urban ecosystem assets from an ecosystem service perspective. More specific “narrow” urban ecosystem asset types include:

- Built-up areas / Grey infrastructure: these areas have no ecological functioning and no ecosystem services will be estimated from these assets, but these are included for completeness (i.e. so that the entire land area is included). This includes roads, buildings and other types of grey infrastructure (a non-exhaustive list of “specific urban features). Where green/blue infrastructure is integrated into built-up areas / grey infrastructure (e.g. street trees / green roofs) this land area is captured separately in the account (under “green/blue infrastructure asset features that are integrated into the built environment).

- Green-blue infrastructure asset features that are integrated into the built environment: where possible high resolution datasets will be used to identify these features which include green roofs, green walls and street trees.

- Highly managed assets: these ecosystem assets occupy significant land area within the urban fabric (rather than being integrated into the built-up area / grey infrastructure) and are conserved / managed primarily for their socio-economic benefits, with significant annual expenditures being incurred on their upkeep. This includes parks, roadside verges, sports grounds, private and public gardens.

The classification in Table 3.1.1. is a *framework* to be adopted flexibly depending on the data available (the specific asset descriptions included in Table 3.1.1. are only illustrative of a potential classification). This means that the classification of “narrow” urban asset types that is used within an EEA will depend on the data that is available to enable the spatial mapping of these assets.

The proposed classification in Table 3.1.1. is consistent with SEEA EEA guidance on thematic accounting (UN, 2020) specifically section 13.90 which states:

“Urban ecosystems are an ecosystem type included in the SEEA EA ecosystem classification and changes in urban extent are tracked in aggregate relative to other ecosystem types in the ecosystem extent account. However, the compilation of a thematic account for urban areas provides the opportunity for a more detailed accounting for urban area sub-types with the broader framing provided by the IUCN Global Ecosystem Typology which defines a broad ecosystem functional group covering urban ecosystems (Class T7.4). This compilation follows the same general guidelines as ecosystem accounting more generally, including the development of extent, condition and services accounts. However, reporting on urban green and blue assets at a more detailed scale within the continuous urban extent can be seen as a distinguishing factor”.

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Table 3.1.1. Proposed classification of ecosystem assets for urban Melbourne EEA (non-exhaustive)[a]

Broad asset type	Narrow urban asset type		
1. Marine	9.1. Urban marine		
2. Alpine	9.2. Urban alpine		
3. Shrubland	9.3. Urban shrubland		
4. Grassland	9.4. Urban grassland		
5. Forest/woodland	9.5. Urban forest/woodland (e.g. >0.5ha)		
6. Coastal margins	9.6. Urban coastal margin	9.6.1. Urban beach	
		9.6.2. Urban bathing waters	
7. Farmland	9.7. Urban farmland		
8. Freshwater and wetland	9.8. Urban freshwater / wetlands	9.8.1. Urban rivers	
		9.8.2. Urban lakes and ponds	
		9.8.3. Urban wetlands	
9. Urban (catch-all)	9.9. Built up areas	9.9.1. Roads	
		9.9.2. Buildings	
		9.9.3. Other grey infrastructure	
	9.10. Integrated green-blue infra.	9.10.1. Green roofs	
		9.10.2. Street / city trees	
	9.11. Highly managed assets	9.11.1. Parks	
		9.11.2. Sports grounds	
		9.11.3. Private gardens	
		9.11.4. Public gardens	9.11.4.1. Botanic gardens
			9.11.4.2. Market gardens
		9.11.5. Road verges	

[a] Note the italicised assets labelled 1 to 8 in the broad asset column are outside of an urban account but represent (along with urban) the potential set of mutually exclusive environmental-economic accounts for Victoria

The approach to capturing the extent of the nine broad assets within the urban Melbourne EEA boundary (the rural-urban interface) is to use the VLCTS database. The VLCTS has 19 land cover classes, which the study team has mapped across to the nine broad assets. This mapping of VLCTS land cover classes to the broad assets has been informed by the descriptions of each class (detailed in Annex 9), as well as interrogating other datasets such as the Victorian Land Use Information System (VLUIS). For example, investigating the VLCTS and VLUIS datasets together indicates that the *Exotic pasture / grassland* land cover class areas, which are defined as 'herbaceous pastures that are predominantly composed of nonindigenous species' (DELWP 2020), predominantly cover farming land use areas. Therefore, this land cover class has been attributed to the *Farmland* broad asset class rather than to *Grassland*.

Disaggregation to "narrow" ecosystem assets using more specific datasets, such as *VPA Open Space* and *Vicmap Hydro* is undertaken where this is useful for assessing the provision of ecosystem services, such as for highly managed assets (e.g. parks) and rivers, respectively, which may have unique characteristics that determine a specific capacity to deliver ecosystem services (e.g. significant capacity to provide recreational opportunities due to the proximity of these assets to people, visitor facilities etc).

The classification is hierarchical, with broad ecosystem assets (using the VLCTS) being classified based on land cover in the first instance and narrow assets being a subset of the broader asset classification. Land cover is (re-) classified more specifically (into "narrow" assets within a broad ecosystem asset class) using other datasets to acknowledge certain features (e.g. urban lakes, ponds, wetland), land uses (e.g. urban agricultural production, sports grounds) and designations (e.g. national park) in order to be informative from an ecosystem services perspective. In order to avoid double counting, the study team overlaid different datasets to ensure that a given land area enters into the account once.

Highly managed and integrated assets (e.g. green roofs and walls) are included in this Melbourne assessment despite not strictly being "natural" ecological systems (i.e. these assets are constructed by humans). This is because these assets exhibit (and have been designed to provide) ecological functioning and to deliver ecosystem services and human health and wellbeing benefits, in the same way that "natural" ecosystem assets function and are productive. Moreover, the definition of "natural" ecosystems is not straightforward given the modifications that have been made to ecosystems by humans over time, in order to support the delivery of socio-economic benefits. This is most evident in the use of "farmland" (a highly managed and modified land use) as a broad asset type within the classification that is set out in Table 3.1.1. For this reason, the term "natural" assets is avoided in this Melbourne account, in favour of ecosystem assets.

3.1.2. Results

Table 3.1.2. reports the total area (in hectares) of each of the broad ecosystem assets and narrow (more specific) urban assets within metropolitan Melbourne and Figure 3.1.1. illustrates their spatial distribution.

Unofficial

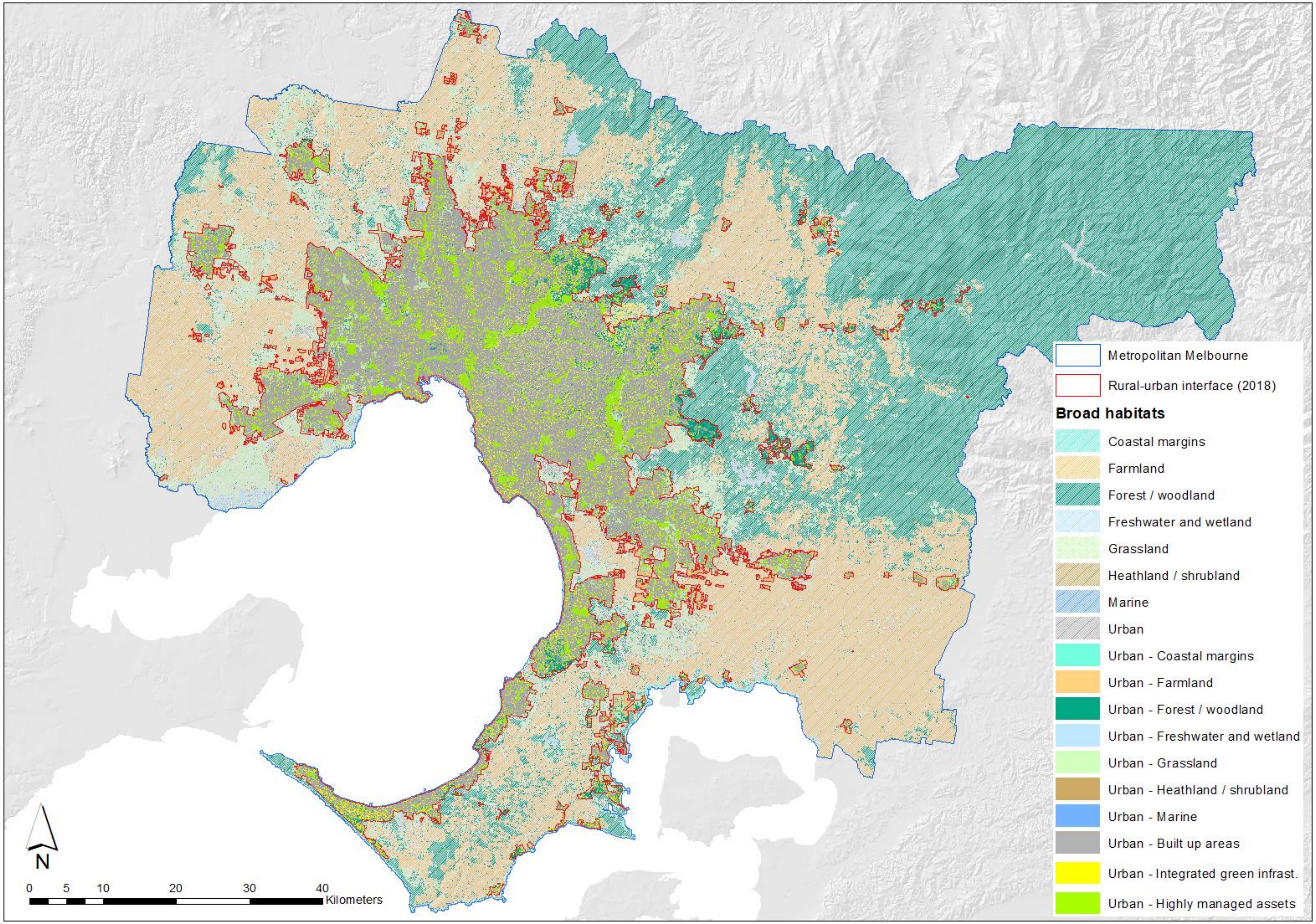
Table 3.1.2. Extent of urban ecosystems within Melbourne in 2019 (DELWP, 2020)

Broad asset type	Area (ha.)	Urban asset type *(within the rural-urban interface)*	Area (ha.)	Narrow urban asset type *(within the rural-urban interface)*	Estimate	Metric
1. Marine	-	9.1. Urban marine	0	-	-	-
2. Alpine	-	9.2. Urban alpine	0	-	-	-
3. Shrubland	-	9.3. Urban shrubland	1,756	-	-	-
4. Grassland	-	9.4. Urban grassland	15,799	-	-	-
5. Forest / woodland	-	9.5. Urban forest / woodland	13,870	-	-	-
6. Coastal margins	-	9.6. Urban coastal margin	89	-	-	-
7. Farmland	-	9.7. Urban farmland	5,749	-	-	-
8. Freshwater and wetland	-	9.8. Urban freshwater and wetland[8]	2,794	9.8.1. Urban rivers	690	ha.
					731	*km*
				9.8.2. Urban lakes and ponds	1,063	ha.
				9.8.3. Urban wetlands	194	ha.
				9.8.4. Other freshwater and wetland	847	ha.
9. Urban	214,378	9.9. Built up areas	126,599	-	-	-
		9.10. Integrated green infrastructure[9]	15,829	9.10.1. Street / city trees[10, 11]	15,810	ha.
					5,201,645	*no.*
				9.10.2. Green roofs[12]	19	ha.
		9.11. Highly managed assets[13]	31,892	9.11.1. Parks and Gardens - Public	5,136	ha.
				9.11.2. Natural open space - Public	8,397	ha.
				9.11.3. Conservation Reserves - Public	766	ha.
				9.11.4. Sports and Recreation - Public	5,707	ha.
				9.11.5. Sports and Recreation - Private	1,954	ha.
				9.11.6. Sports and Recreation - Restricted	1,568	ha.
				9.11.7. Education institutions - Private	1,810	ha.
				9.11.8. Education institutions - Restricted	3,432	ha.
				9.11.9. Transport and service reservations - Restricted	1,815	ha.
				9.11.10. Other - Public	96	ha.
				9.11.11. Other - Private	103	ha.
				9.11.12. Other - Restricted	1,107	ha.
		Catch-all urban tree numbers[14]			*1,654,923*	*no.*
Total			**214,378**			

[8] Includes data from Vicmap Hydro dataset.
[9] While this asset class could include integrated blue infrastructure, such as artificial ponds found in parks, these are harder to distinguish from the spatial dataset and have been included under 'Urban freshwater and wetland'.
[10] Based on data from Vicmap Vegetation – Tree Urban and Vicmap Vegetation – Tree Extent datasets for metropolitan Melbourne, adjusted to cover entire assessment area based on average density rate
[11] The extent and number of street / city trees includes only those which fall within built up areas, but excluding trees in parks and other highly managed assets.
[12] Based on data from University of Melbourne
[13] Based on data from VPA Open Space dataset
[14] Urban trees exist across many different broad ecosystem assets including urban forests, parks and as street/city trees in built up areas. Whilst the 5.2million street/city trees that are integrated into built-up areas / grey infrastructure across Melbourne have been split out into a specific entry in the extent account, the trees that exist in parks and urban forests etcetera are combined within this catch-all entry into the extent account.

Unofficial

Figure 3.1.1. Spatial distribution of urban ecosystems within Melbourne in 2019 (DELWP, 2020)



Unofficial

Box 3.1.1. includes the results from mapping the extent of nine mutually exclusive ecosystem assets (see Box 2.3.1.) within the broader metropolitan Melbourne region for 2019 (i.e. beyond the rural-urban interface, see Section 2.3 and Figure 2.3.2.). This baseline extent information can be used in future accounts to report on the extent of urban development (i.e. how land use / cover has changed) within the broader metropolitan Melbourne region over time.

Box 3.1.1. Mapping the extent of broad ecosystems within metropolitan Melbourne

Table 3.1.3. reports the extent of broad ecosystems within the Melbourne metropolitan area using the VLCTS. It shows that there is a total of 231,579 hectares of urban area within the metropolitan Melbourne region consisting of 214,378 hectares of urban ecosystem assets (i.e. the area that is assessed under the urban Melbourne EEA including all broad urban ecosystems such as urban forests etc that are within the rural-urban interface) and an additional 17,201 hectares of peri-urban area that exists outside of the rural-urban interface in the broader metropolitan Melbourne region.

Table 3.1.3. Extent of broad ecosystem assets within metropolitan Melbourne in 2019 (DELWP, 2020)

Broad ecosystem asset type	Extent (ha.)
1. Marine	2,494
2. Alpine	0
3. Shrubland	3,793
4. Grassland	75,959
5. Forest / woodland	301,520
6. Coastal margins	3,166
7. Farmland	266,814
8. Freshwater and wetland	13,943
9. Urban[a]	231,579
Total	**899,237**

[a] This 231,579ha consists of 214,378ha within the rural-urban interface which is treated as “urban” for the purposes of this urban Melbourne EEA. The remaining 17,201ha is considered peri-urban area within the broader metropolitan Melbourne area.

Table 3.1.4. summarises the uncertainty associated with these results and shows that there is medium uncertainty associated with the extent mapping as the evidence on the broad ecosystem types doesn’t exactly map across from the VLCTS so some assumptions have had to be made in order to classify/re-classify land cover under the nine broad ecosystem types and the resolution of that data is 25 metres.

Unofficial

Table 3.1.4. Uncertainty assessment - extent account

	Uncertainty in…		
	Evidence	Assumptions	Total
Explanation	- Estimates of the extent of the 9 broad ecosystems is constructed using existing land cover data from VLCTS. The 19 VLCTS classes do not align directly with the 9 ecosystem types. - The resolution of the data is 25 metres, with one VLCTS class displaying one of the 19 land cover classes. - Additional spatial datasets were used to classify more narrow assets within the broad ecosystems, as well as reclassify certain ecosystems where more fine grain spatial data was available. These datasets include: o VLUIS (agriculture / farmland); o VPA Open Space (parks and open space); o Vicmap Hydro (water features); o Vicmap Vegetation (urban trees); and o University of Melbourne (green roofs).	- Assumptions have been made to map the 19 VLCTS classes across to the 9 broad ecosystem types. - Some re-classification of land / water cover classes (e.g. natural low cover and water) has been needed using other datasets (e.g. land use and estuary extent data) in order to provide a coherent / logical extent information for each of the 9 broad ecosystems, this has required some justifiable assumptions which are consistently applied and documented.	Medium
Rating	2	2	4

3.1.3. Discussion

The analysis of urban ecosystem extent within Melbourne (see Table 3.1.2. and Figure 3.1.1.) shows that the urban area (defined as being within the rural-urban interface) covers approximately 214,000 hectares and that:

- This consists mostly of built-up areas / grey infrastructure (approximately 127,000 hectares or 59 per cent) consisting of residential, commercial and industrial areas, including roads and buildings.
- The remaining approximately 88,000 hectares (or 41 per cent) consists of the natural ecosystem assets within the urban extent, including the re-classification of built-up areas to integrated green infrastructure such as street trees where these exist.
- Highly managed assets, including parks, open space, reserves and sports and recreation assets, make up the largest urban ecosystem asset type (approximately 32,000 hectares or 15 per cent).
- Integrated green infrastructure, consisting of street / city trees and green roofs located within built-up areas, covers approximately 16,000 hectares or 7 per cent.
- Urban grassland (approximately 16,000 hectares or 7 per cent) and urban forest / woodland (approximately 14,000 hectares or 6 per cent) also occupy significant areas within the urban extent.

The distribution of ecosystems shows that while the majority of the urban area consists of grey infrastructure, highly managed assets (such as parks) and integrated green infrastructure (such as street trees) feature consistently throughout the region.

3.2. Ecosystem asset condition

3.2.1. Methodology

The key objective of the condition account is to monitor changes in the *capacity* of ecosystems to deliver ecosystem services (eftec et al, 2017). Relevant ecosystem condition metrics/indicators *do* include conventional ecological definitions of ecosystem condition (e.g. ranging from degraded to pristine ecological condition). In addition, to be useful from a policy perspective, the reviewed accounts also include broader metrics related to natural resource management and productivity, as follows (see Annex 5 for more information on the review of global and Victoria specific literature of relevance):

- **Ecological condition metrics**: indicators of ecosystem health (as measured for the purposes of informing the ecological management of assets) measuring the concept of ecological integrity which is of relevance in its own right as per SEEA-EA guidance (pers. comm Carl Obst). It can also be assumed that ecosystem assets that are in good ecological health will generally have a greater capacity to generate ecosystem services than assets in poor ecological condition. Ecological condition is captured in the account through metrics which capture:

- The intrinsic value of biodiversity which will *not* be valued in monetary terms in the account, but which are valued by society in both "use" (e.g. nature watching) and "non-use" (e.g. existence and option value) terms.

- Ecosystem asset characteristics for which there is scientific consensus on their importance in underlying the productive capacity of ecosystems such as the type of tree species being an important characteristic in determining the provision of carbon capture and storage by forests (for example).

UK environmental-economic accounts (ONS, 2016; AECOM, 2016) classify these ecological condition indicators based on the SEEA EEA condition categories of biodiversity, soil, water and carbon and this classification is use in the urban Melbourne EEA.

In order to be useful from a policy perspective, the reviewed accounts also include broader asset characteristics related to natural resource management and productivity, as follows:

- **Socio-economic characteristic metrics:** which capture the human interaction with the environment including ecosystem location relative to beneficiaries, cultural assets, built assets, governance and management. These broader characteristics are important determinants of the delivery of ecosystem services and the associated socio-economic benefits by ecosystem assets as follows:

- Location of ecosystem assets relative to beneficiaries. For example, accessible green space within 400m of residence could be a relevant metric to understand the "condition" of the environment for recreation opportunities.

- Cultural assets that are tangible/physical ecosystem assets that are of historic or contemporary cultural heritage (e.g. arboreal avenues of culture) or of value to Traditional Owners living cultural heritage as were captured (from Aboriginal Affairs Victoria) in the Valuing Victoria's Parks account (DELWP and PV, 2015) through a "cultural assets account". The actual inclusion of such information in future iterations of the Melbourne EEA will depend on what is deemed to be appropriate by the Traditional Owners of the lands within the assessment boundary.

- Built assets that provide an important contribution to economic activity such as access facilities (e.g. paths and bridleways which are important for recreation services) and built assets of historic cultural heritage, as captured in a built asset account as part of the DELWP and PV (2015) study on Victoria's Parks. The visitor experience to the natural environment is enhanced by these other (non-natural) capitals and this should be accounted for as it is useful to understand from a policy perspective.

Unofficial

- Governance and management practices: including protected status designations (important for conservation) to capture how humans are managing the natural environment to deliver ecosystems services of value to society as included in UK environmental-economic accounts (ONS, 2016; AECOM, 2016).

The information within the urban Melbourne EEA will therefore capture ecological integrity as per SEEA-EA guidance but extend beyond this to also capture other variables that are necessary to co-produce ecosystem services from ecosystem assets (Dickie et al, 2014). Annex 5 includes a non-exhaustive list of potential metrics and data sources that could be used to populate the condition account for the Melbourne-EEA.

3.2.2. Results

The condition account is set out in Table 3.2.1. including a range of ecological condition metrics, socio-economic characteristics, a list of the primary ecosystem services these indicators support, the resolution of the data used, its geographic coverage, the source and year of the data as well as the metrics and estimates of the urban Melbourne EEA study area. The uncertainty rating for the condition account is presented for each metric in Table 3.2.2. based on the robustness of evidence sources and methodological assumptions. The distribution of ecosystem condition across the urban Melbourne EEA study area is also presented as maps and tables as follows:

- Vegetation condition score in Figure 3.2.1. and by tenure in Table 3.2.3.
- Habitat importance for threatened species in Figure 3.2.2. and by tenure in Table 3.2.4.
- Threatened flora observations in Figure 3.2.3. and by classification in Table 3.2.5.
- Threatened fauna observations in Figure 3.2.4. and by classification in Table 3.2.6.
- Percentage tree cover in Figure 3.2.5.
- Above ground biomass in Figure 3.2.6. and by tenure in Table 3.2.7.
- Landslide and coastal acid sulphate soil susceptibility in Figure 3.2.7.
- Index of Stream Condition in Figure 3.2.8. and by condition score grouping in Table 3.2.8.
- Index of Estuary Condition in Figure 3.2.9. and by condition score grouping in Table 3.2.9.
- Flood retardation basins in Figure 3.2.10.
- Site carbon stock in Figure 3.2.11.
- Light pollution in Figure 3.2.12.
- Proximity of dwellings to open space in Figure 3.2.13.
- Historic cultural heritage in Figure 3.2.14.
- Designated Water Supply Catchments, Ramsar Wetlands, National Parks and other reserves in Figure 3.2.15.
- Piers, jetties, boat access points and boating restrictions zones in Figure 3.2.16.
- Walking tracks and bicycle paths in Figure 3.2.17.

Unofficial

Table 3.2.1. Headline condition account for the urban Melbourne EEA area

Condition category / Indicator	Ecosystem	Primary ecosystem service being supported	Resolution	Source	Year	Metric	Condition Score Urban Melbourne EEA area	Uncertainty
Ecological condition - Biodiversity								
Native vegetation condition	Terrestrial	Existence / option value	75m grid	DELWP (2017)	2017	Score 1 -100	8	Medium
Habitat importance-threatened species	Terrestrial	Existence / option value	225m grid	DELWP (2016a)	2016	Score 1-100	24	Medium
Threatened flora	Terrestrial	Existence / option value	Point data	DELWP (2021)	2021	Species count	111	Medium
Threatened fauna	Terrestrial	Existence / option value	Point data	DELWP (2021)	2021	Species count	103	Medium
Vegetation cover	Terrestrial	Existence / option value	1:5k	DELWP (2019a)	2018	% grass	16	Medium
						% shrub	6	Medium
						% tree	14	Medium
Vegetation biomass[a]	Terrestrial	Timber/Global Climate Reg	30m grid	DELWP (2018b)	2017	Tonnes/Ha	167	Low
Apiary Sites on public land	Terrestrial	Food	Point data	DELWP (2021a)	2021	Count	1	Low
Ecological condition – Soil								
Coastal acid sulphate soil susceptibility	Any / All	Saltwater ecosystem services	1:100k	DJPR (2003)	2003	Ha	9,691	Medium
Post fire landslide susceptibility	Terrestrial	Erosion regulation	1:25k	DELWP (2016b)	2010	Ha	1	Medium
Landslide susceptibility	Terrestrial	Erosion regulation	1:250k	DJPR & A.Miner (2017)	2017	Ha (high and v.high)	2,474	Medium
Ecological condition - Water								
Stream condition (index)	Streams	Freshwater ecosystem services	1:25k	DELWP (2010)	2010	Score 0-50	6 (very poor)	Medium
Estuary condition (index)	Estuaries	Freshwater ecosystem services	1:25k	DELWP (2021b)	2021	Score 0-50	23 (poor)	Medium
Retarding basins	Terrestrial	Flood regulation	1:5k	Melbourne Water (2019)	2021	Ha	986	Low
						Count	213	Low
Ecological condition – Carbon								
Carbon stock	All	Global climate regulation	100m grid	DISER (2021)	2019	tCO^2	5,555,655	Medium
						tCO^2 / Ha	26	Medium
						tCO^2e	20,355,921	Medium
Socio-economic characteristics – Location								
Light pollution	All	Aesthetics / Recreation	350m grid	Stare (2021)	2019	Radiance	16	Low
Proximity to open space	All	Recreation	1:5k	AUO (2020)	2018	% of dwellings within 400m of public open space	57	Low
Socio-economic characteristics - Cultural assets								
Historic cultural heritage (partly or wholly within open space)	Terrestrial	Existence / Recreation	Point data	DELWP (2019c)	2019	Ha	4,026	Low
						Count	907	Low
Socio-economic characteristics - Governance and management								
Designated water supply catchment	All	Water purification	1:25k	DELWP (2018c)	2021	Ha	73	Low
						Number	3	
Ramsar Wetlands	Wetlands	Habitat provision	1:25k	DEE (2017)	2021	Ha	204	Low
						Number	3	
National parks and nature reserves	All	Various	1:25k	DELWP (2021c)	2021	Ha	601	Low
						Number	26	
Other conservation reserves	All	Various	1:25k	DELWP (2021c)	2021	Ha	3,017	Low
						Number	139	

Unofficial

Condition category / Indicator	Ecosystem	Primary ecosystem service being supported	Resolution	Source	Year	Metric	Condition Score Urban Melbourne EEA area	Uncertainty
Socio-economic characteristics - Built assets								
Piers and jetties	Marine	Recreation and Tourism	Point data	DELWP (2020)	2020	Count	35	Low
Boat access points	Marine	Recreation and Tourism	Point data	DELWP (2020)	2021	Count	101	Low
Boating restriction zones[b]	Marine	Recreation and Tourism	1:25k	DELWP (2020)	2021	Ha	3,659	Low
Walking tracks	Terrestrial	Recreation and Tourism	1:25k	DELWP (2021d)	2020	Km	894	Low
Bicycle path	Terrestrial	Recreation and Tourism	1:25k	DELWP (2021d)	2020	Km	1,107	Low

[a] Above ground biomass data available on public land only.
[b] Boating and swimming zones are prepared under the Marine Safety Act 2010 with the primary aim of providing a safe environment for recreational water users.

Unofficial

Table 3.2.2. summarises the uncertainty associated with these results and shows that there is low to medium uncertainty given that all datasets used in the condition account did not undertake any further extrapolation or interpretation by the urban Melbourne EEA team and that these datasets were either recorded data (low uncertainty) or interpolated / extrapolated / modelled data from reliable sources (medium uncertainty).

Table 3.2.2. Uncertainty assessment - condition account

	Uncertainty in…		
	Evidence	**Assumptions**	**Total**
Explanation	- The data available does not comprehensively capture the ecological condition or socio-economic characteristics of ecosystem assets within the urban Melbourne EEA area - The robustness of the evidence depends in part on the resolution of the data. - A large number of spatial datasets have been used to build the condition account. Some are based on recorded data (length of bike trails, number of jetties, area of national parks) whilst others are based on interpretations/ extrapolations from recorded data and/or modelled data (vegetation & estuary condition score, landslip, and carbon stock)	- No assumptions have been made by the study team when using data to create the condition accounts, the data has been collated without modification, however each dataset used will have its own inherent assumptions, in particular the datasets that rely on interpolations/extrapolations and modelling as part of their creation. This fact has been used when designating the uncertainty scores to each condition category within Table 3.2.1.	Medium
Rating	2	1	2

Unofficial

Figure 3.2.1. Vegetation condition score (DELWP, 2017)

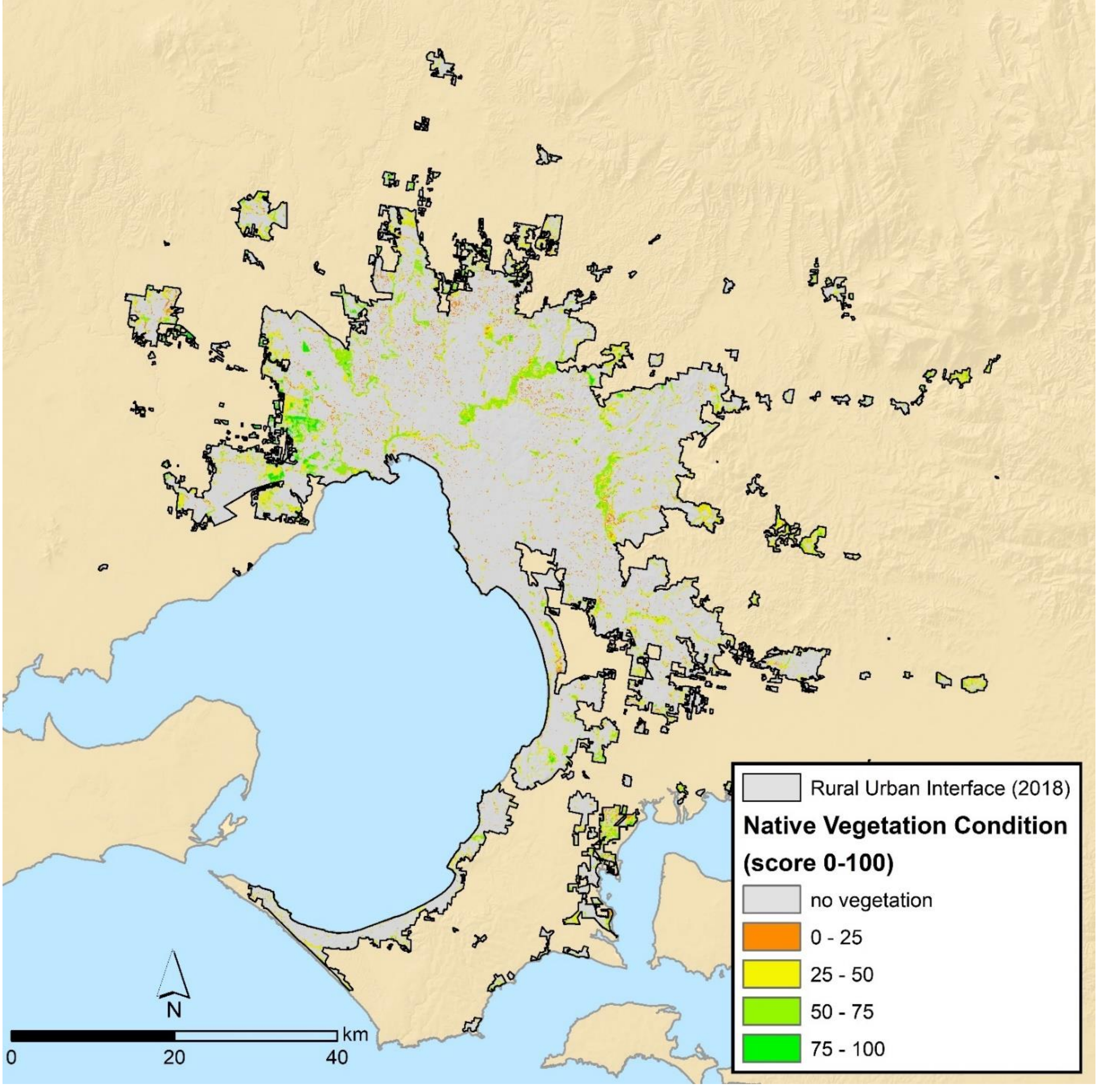


Table 3.2.3. Vegetation condition score per tenure classification

Tenure	Area (Ha)	Mean score (0-100)
Private	202,718	7
Other public land	6,197	19
Other conservation reserves	3,021	45
National Parks act and nature conservation reserves	594	67
Commonwealth land	1,813	15
State Forest	2	80

Unofficial

Figure 3.2.2. Habitat importance for threatened species (DELWP, 2016a)

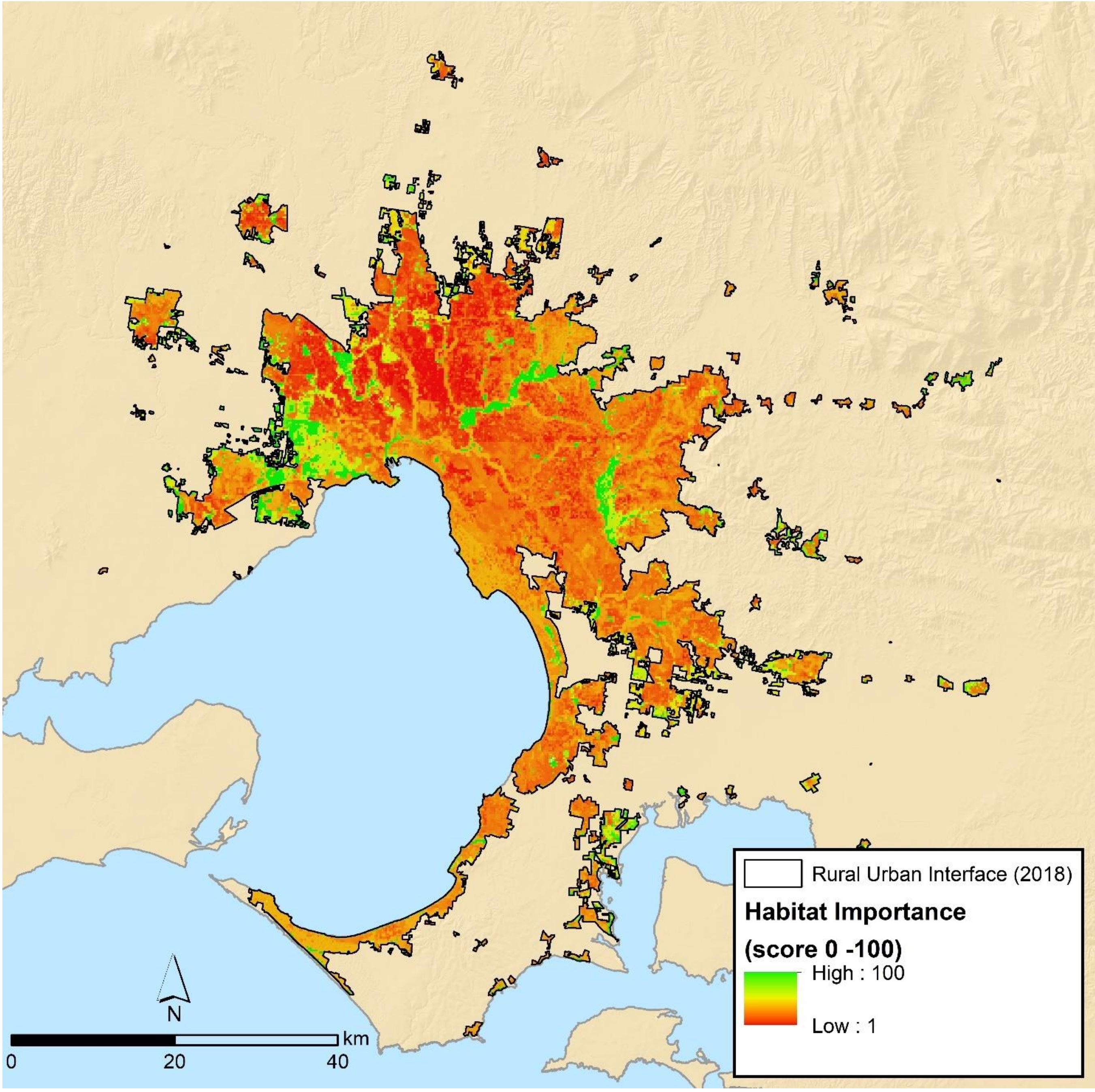


Table 3.2.4. Habitat importance score per tenure class

Tenure	Area (Ha)	Mean score (0-100)
Private	202,738	22
Other public land	6,202	38
Other conservation reserves	2,997	68
National Parks act and nature conservation reserves	582	83
Commonwealth land	1,817	40

Unofficial

Figure 3.2.3. Threatened flora observations (DELWP, 2021)

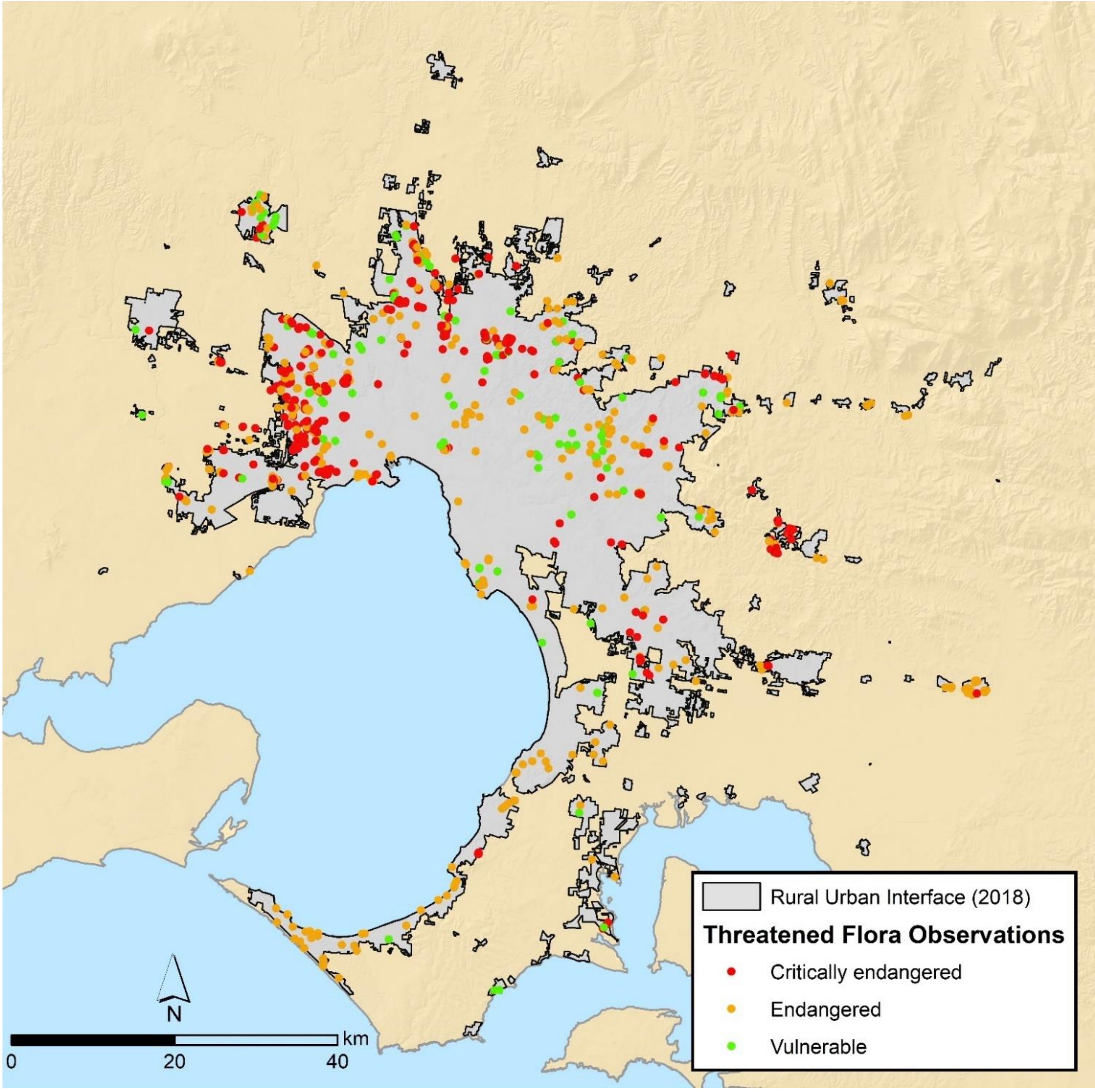


Figure 3.2.5. Threatened flora observations

Threatened flora species count (all instances)			
Critically endangered	Endangered	Vulnerable	Total
30	70	11	111

Unofficial

Figure 3.2.4. Threatened fauna observations (DELWP, 2021)

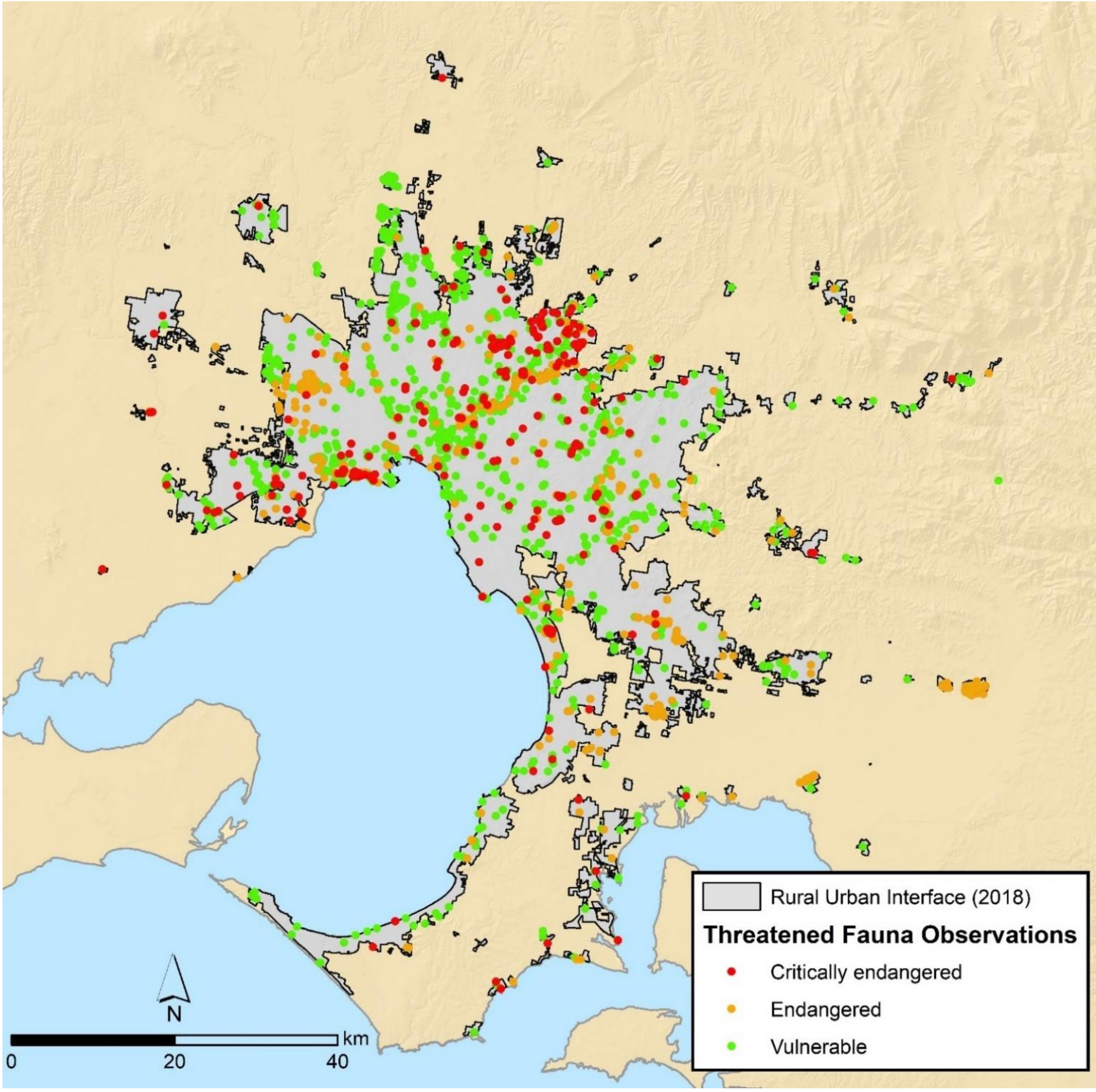


Table 3.2.6. Threatened fauna observations

Threatened species count (all instances)			
Critically endangered	Endangered	Vulnerable	Total
25	41	37	103

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Figure 3.2.5. Percent tree cover (DELWP, 2019a)

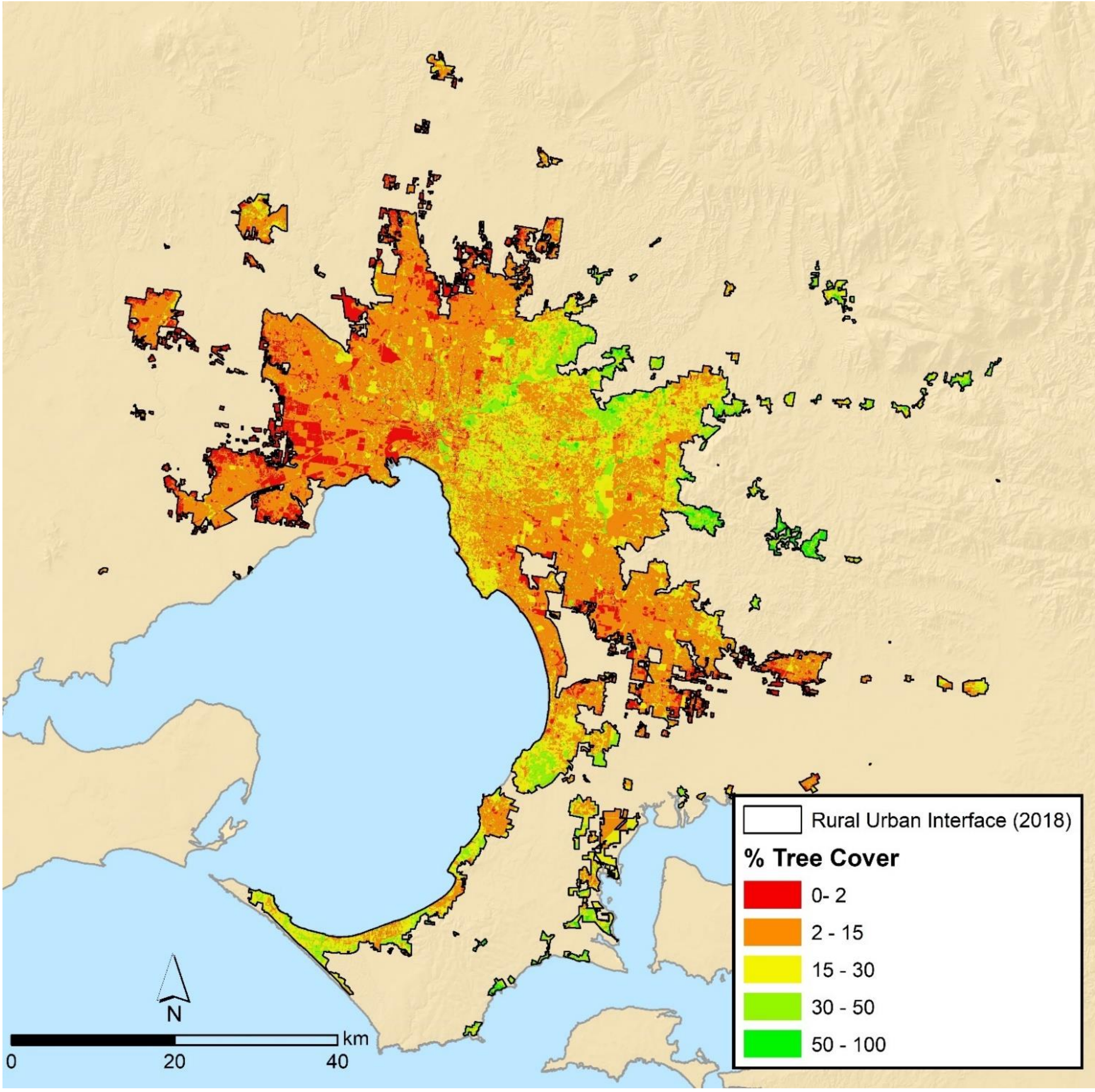

Figure 3.2.6. Above ground biomass (DELWP, 2018b)

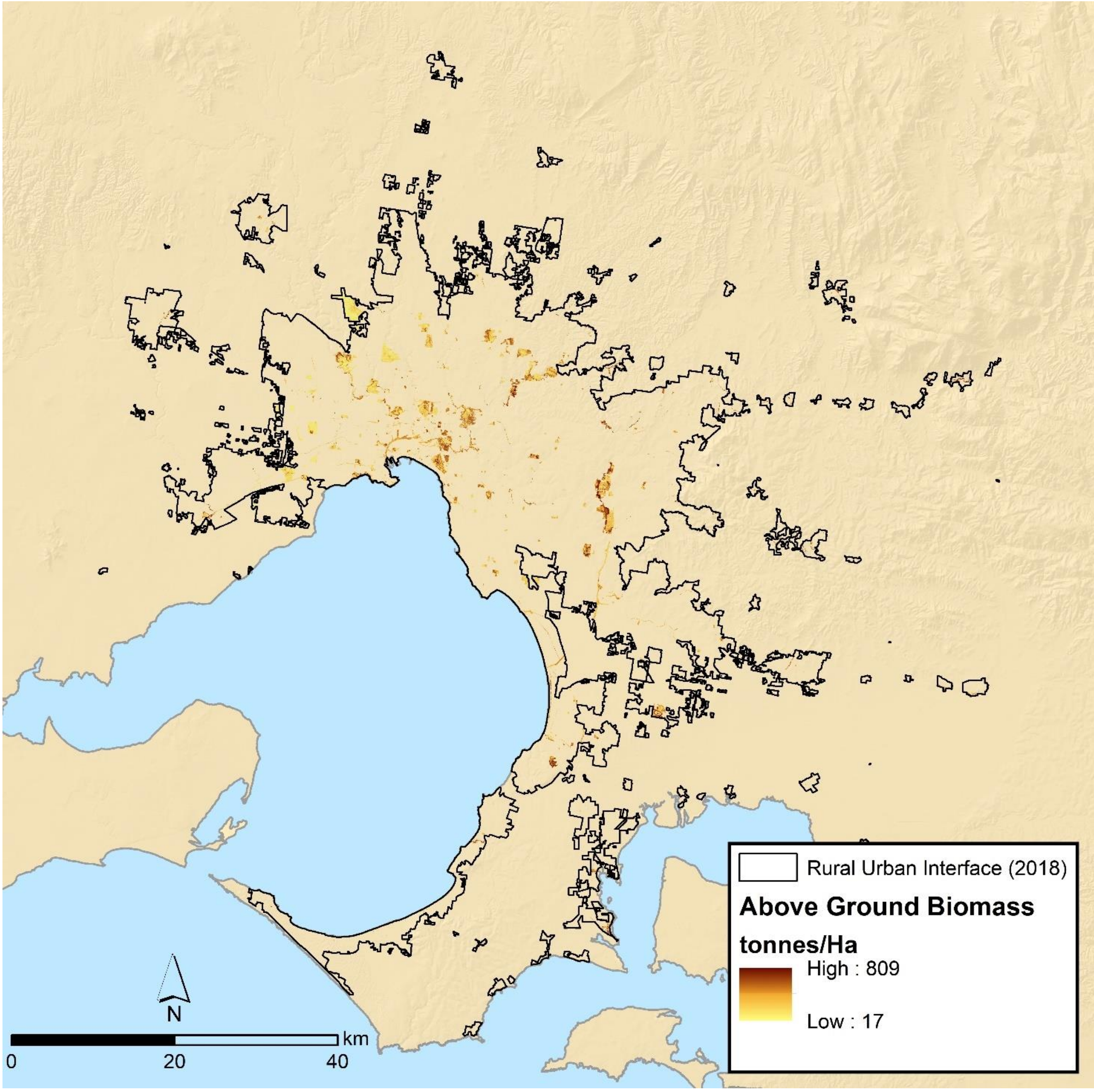

Table 3.2.7. Above ground biomass data per tenure class

Tenure	Area (Ha)	Biomass (t/ha)
Private	*No biomass data for private land*	
Other public land	5,057	183
Other conservation reserves	2,853	201
National Parks act and nature conservation reserves	578	159
Commonwealth land	1,708	83
State Forest	1	361

Figure 3.2.7. Landslide and coastal acid sulphate soil susceptibility (DJPR, 2003; DJPR and Miner A. 2017)

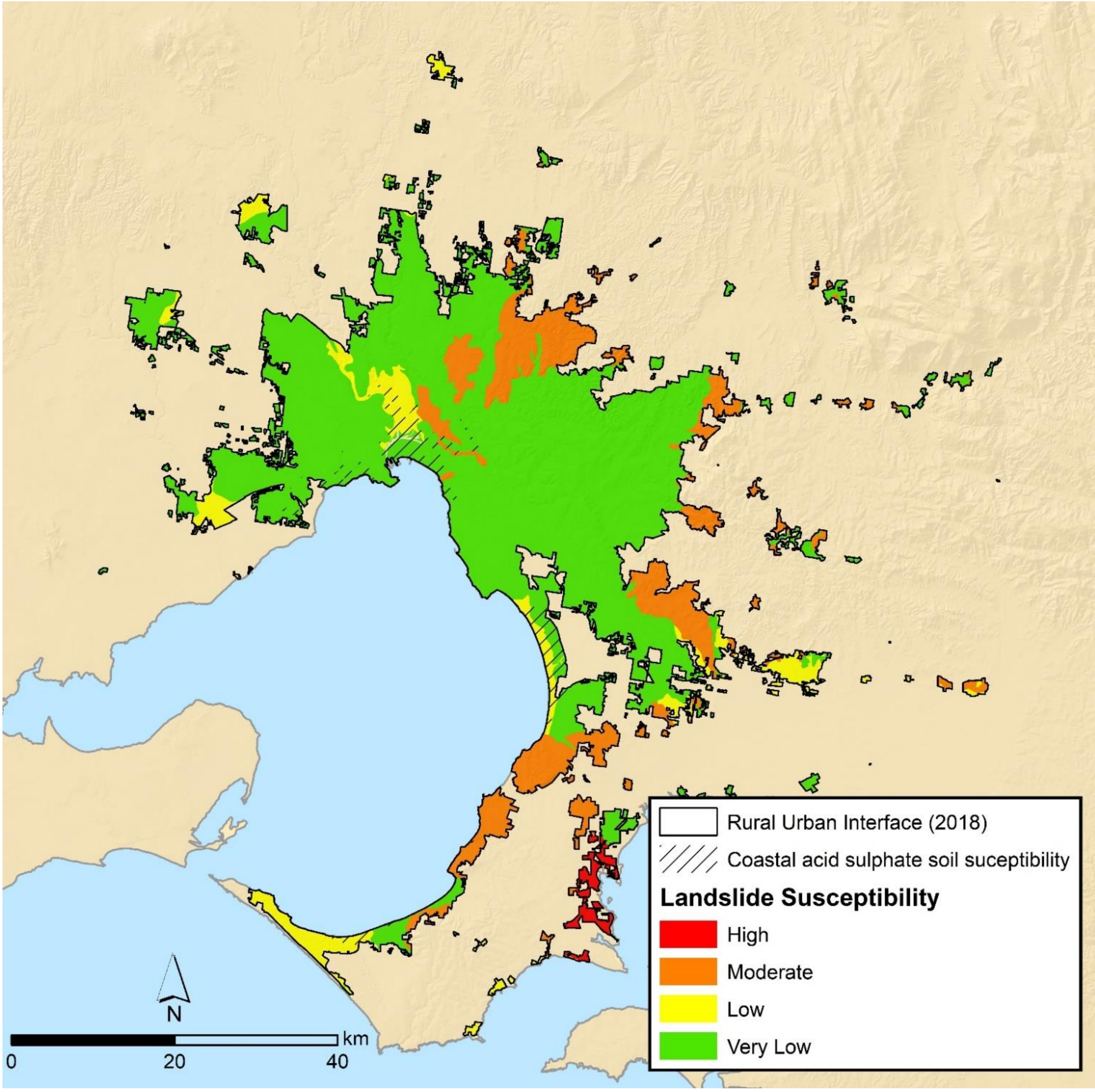

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Figure 3.2.8. Index of stream condition (DELWP, 2010)

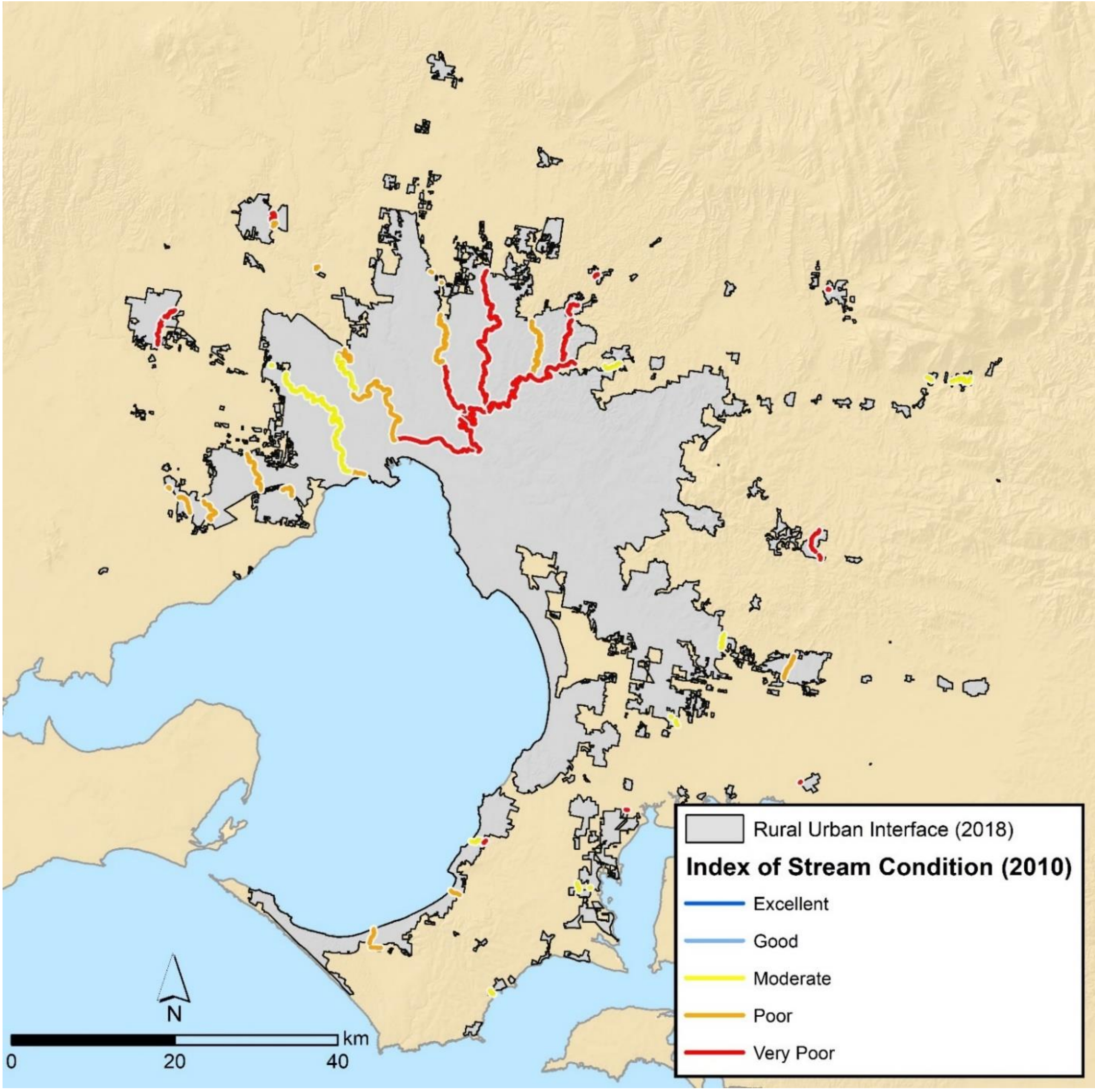

Table 3.2.8. Index of stream condition (2010)

	Index of stream condition (2010)	
	Length (km)	%
Excellent	0.0	0%
Good	0.0	0%
Moderate	44.5	19%
Poor	71.2	31%
Very Poor	117.5	50%

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Figure 3.2.9. Index of estuary condition (DELWP, 2021b)

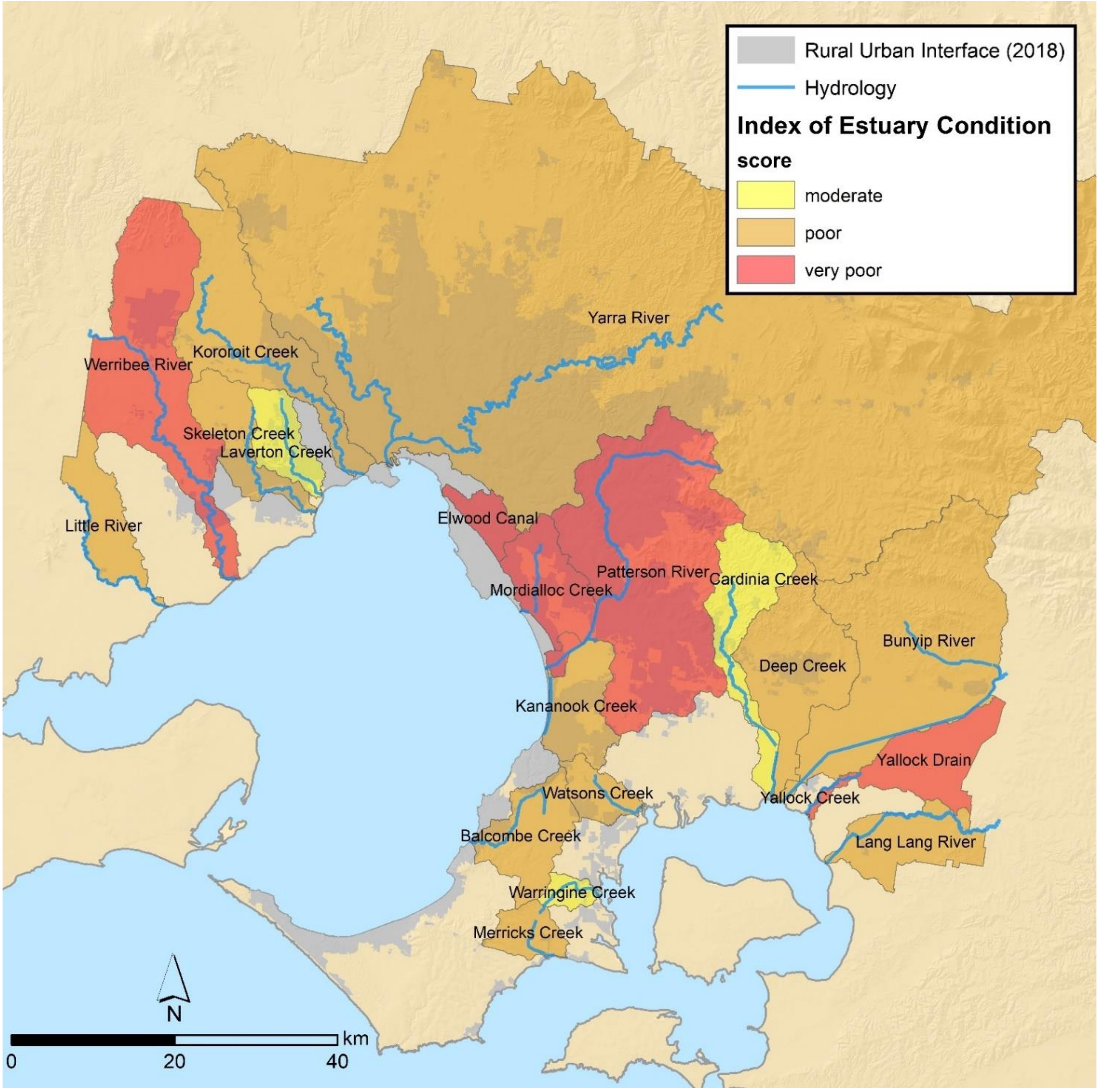

Table 3.2.9. Index of estuary condition (2020)

	Index of estuary condition (2020)	
	Area (Ha)	**%**
Excellent	nil	-
Good	nil	-
Moderate	nil	-
Poor	433	85%
Very Poor	76	15%

Figure 3.2.10. Retarding basins (Melbourne Water, 2019)

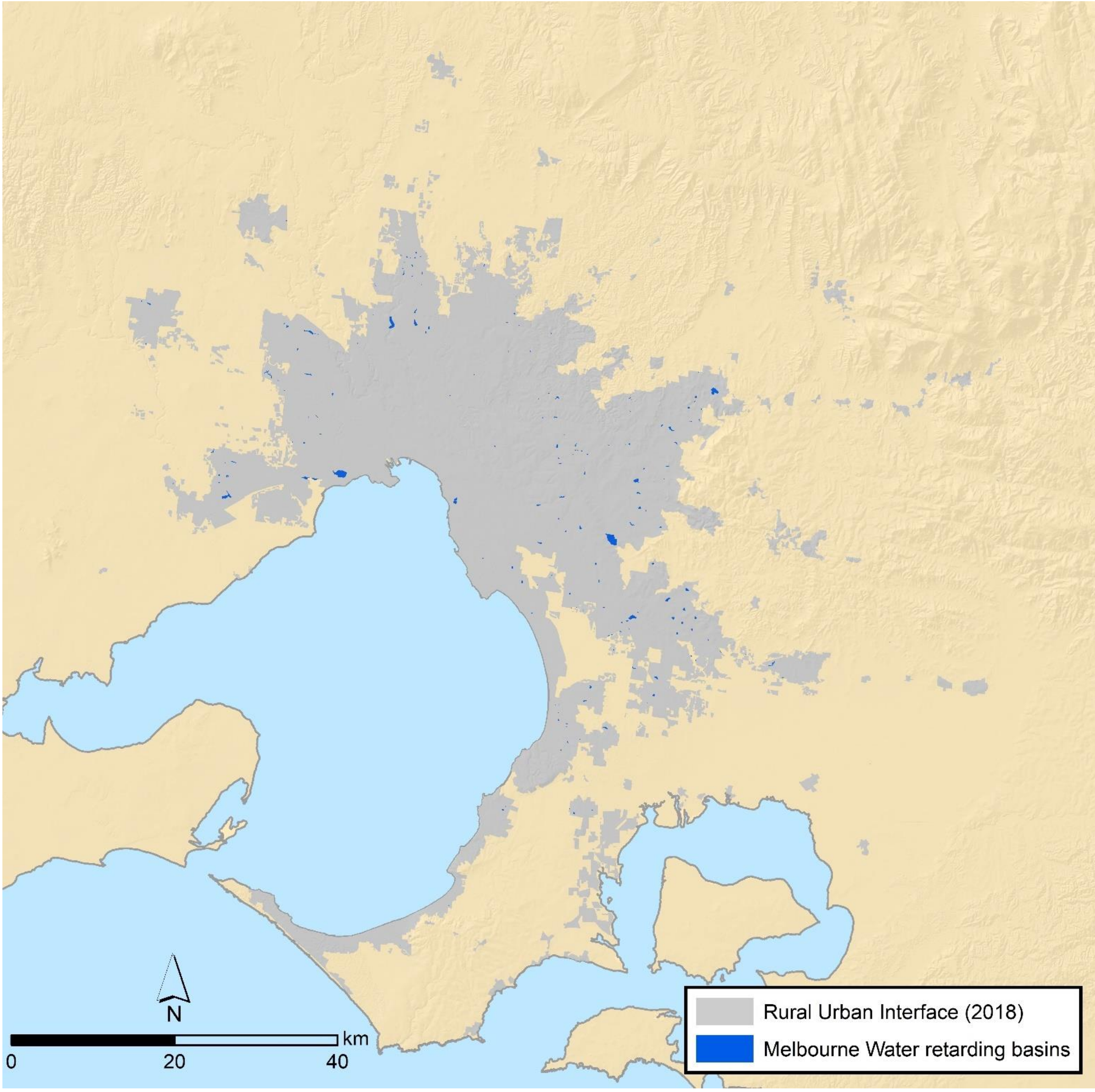
N
0
20
40
km
Rural Urban Interface (2018)
Melbourne Water retarding basins

Figure 3.2.11. Carbon stock (DISER, 2021)

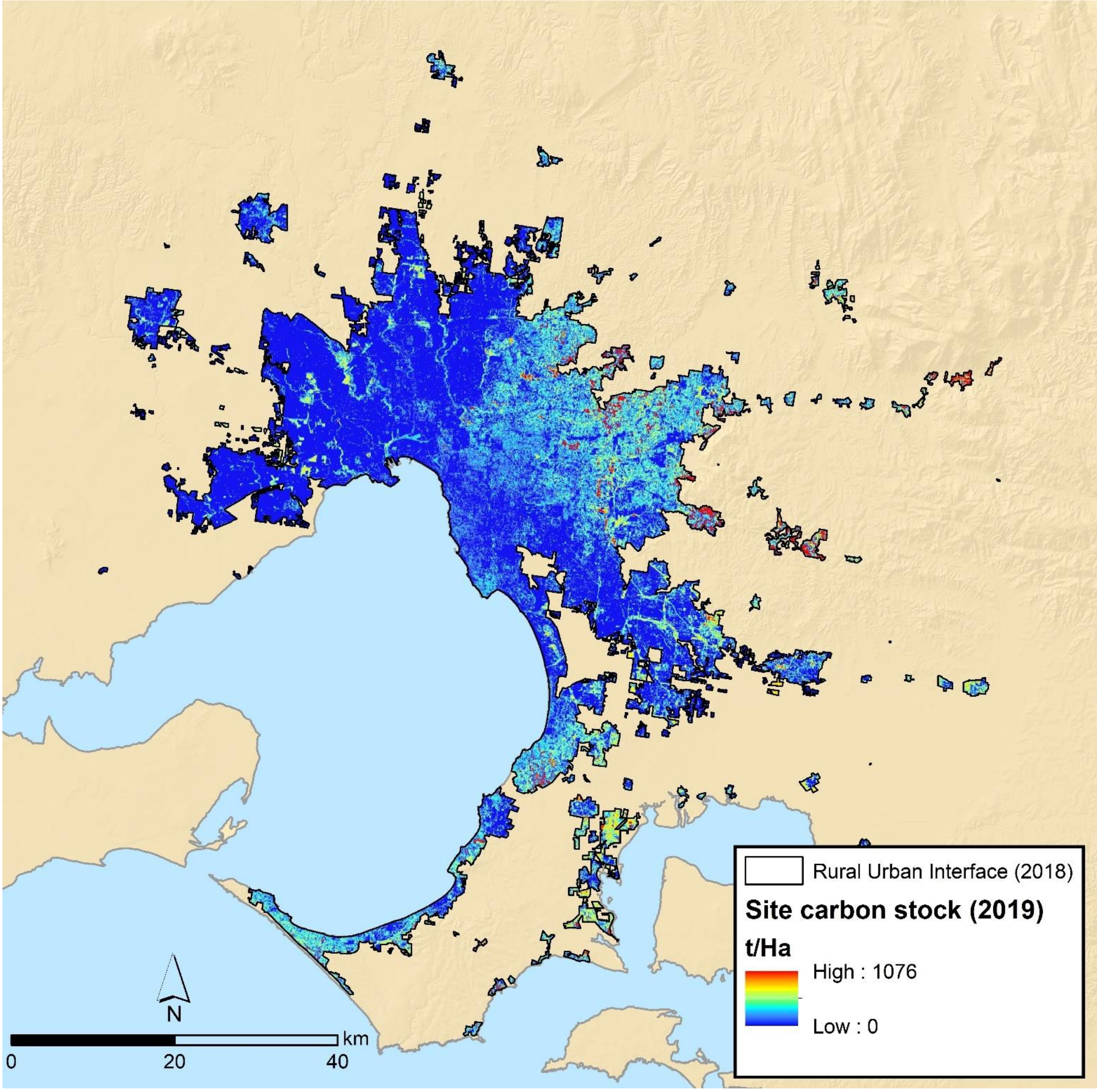

Figure 3.2.12. Light pollution (Stare, 2021)

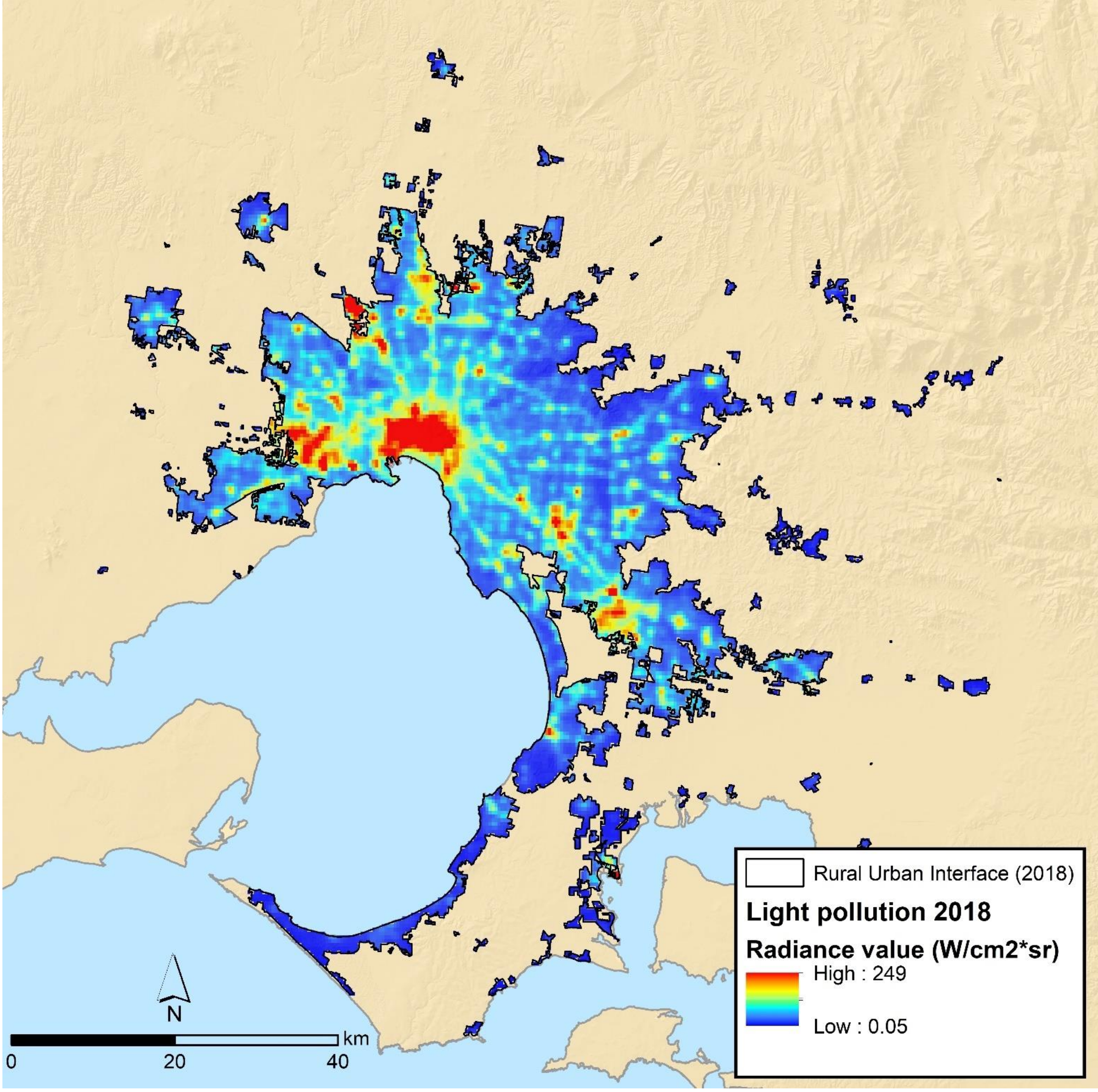

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Figure 3.2.13. Proximity to open space (AUO, 2020)

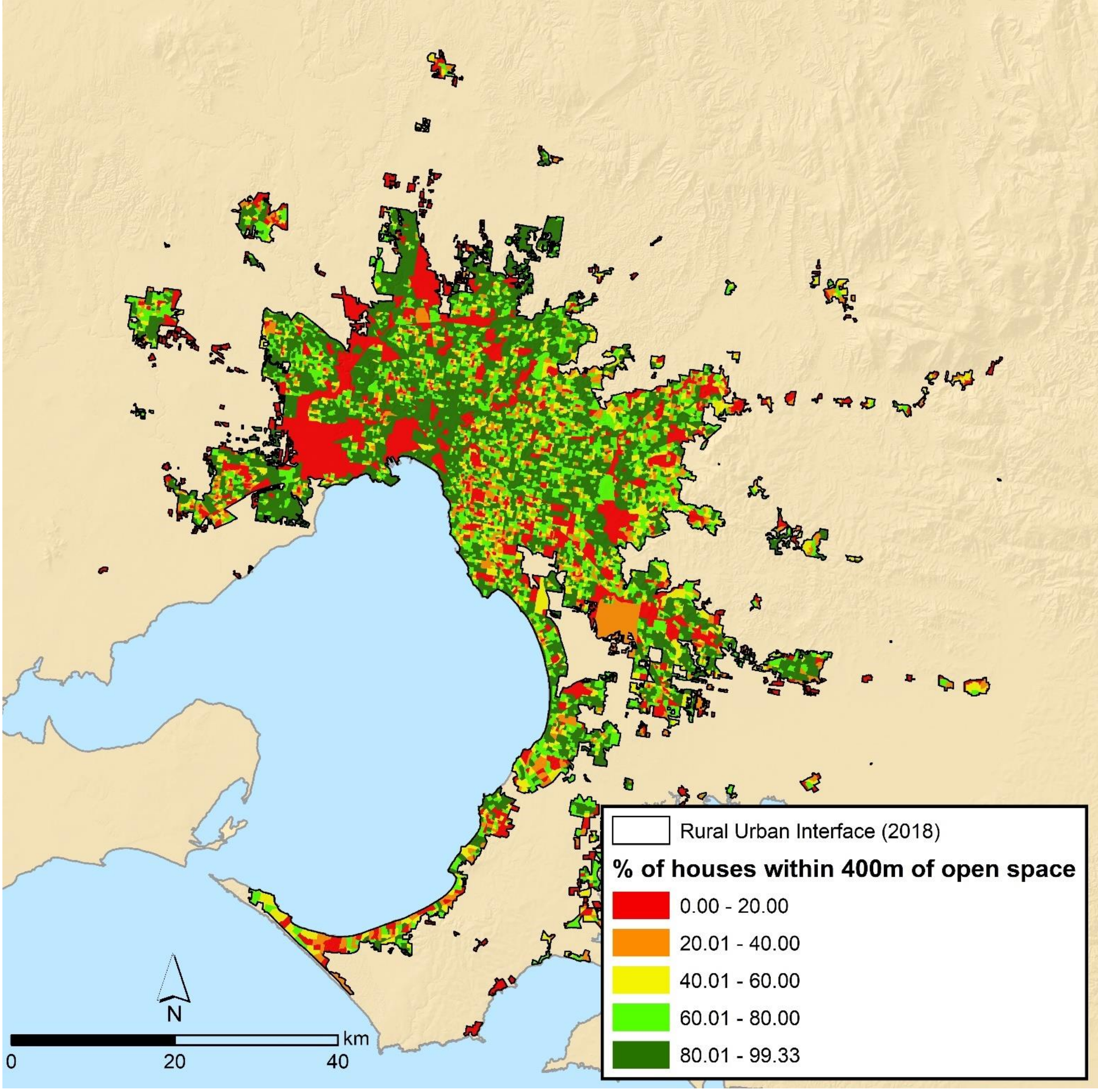

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Figure 3.2.14. Historic cultural heritage (DELWP, 2019c)

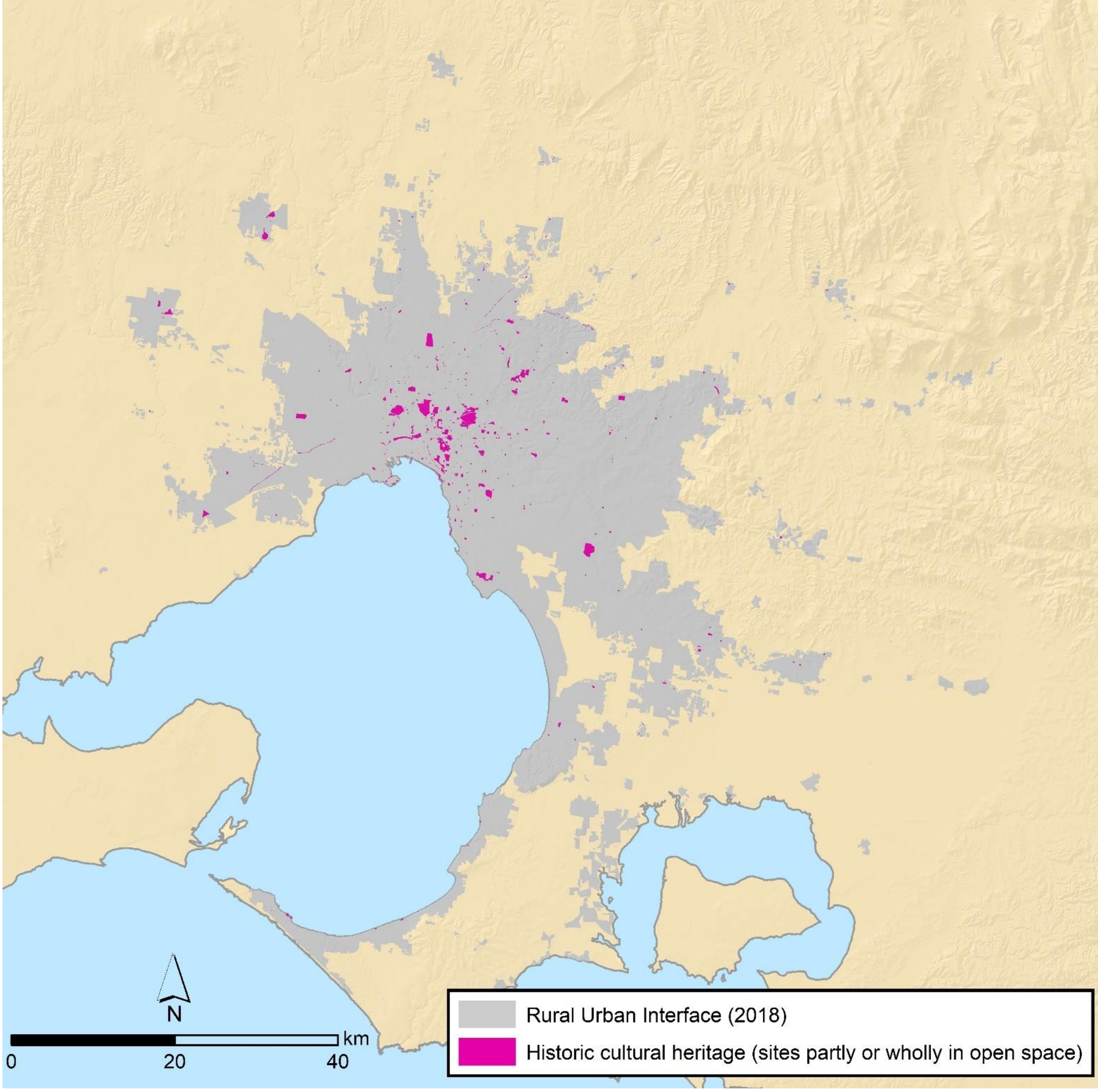

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Figure 3.2.15. Designated water supply catchment (DELWP, 2018c), Ramsar wetlands (DEE, 2017) and National Parks (DELWP 2021c)

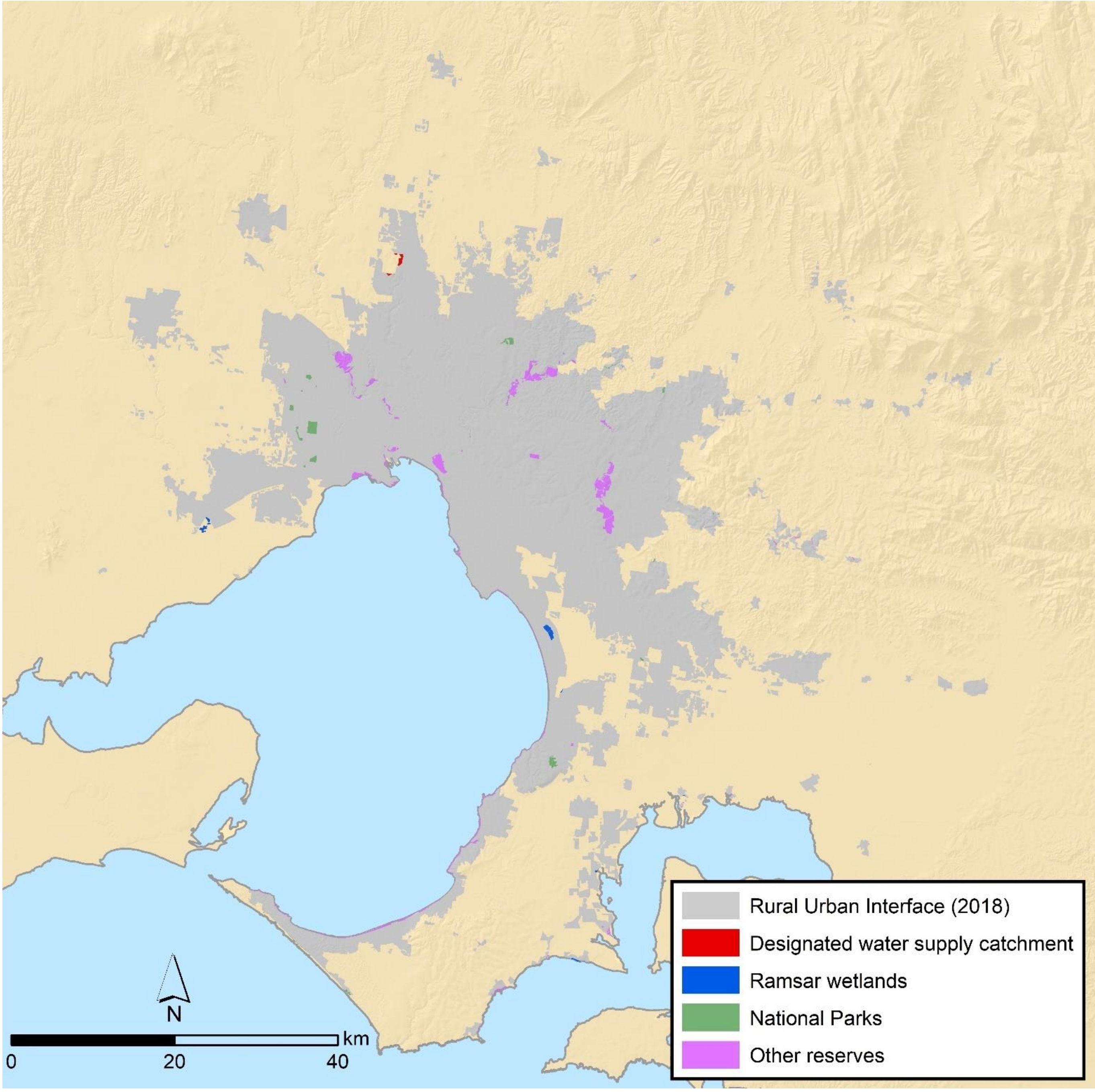

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Figure 3.2.16. Piers and jetties (DELWP, 2020), Boat access points (DELWP, 2020) and Boating Restriction zones (DELWP, 2020)

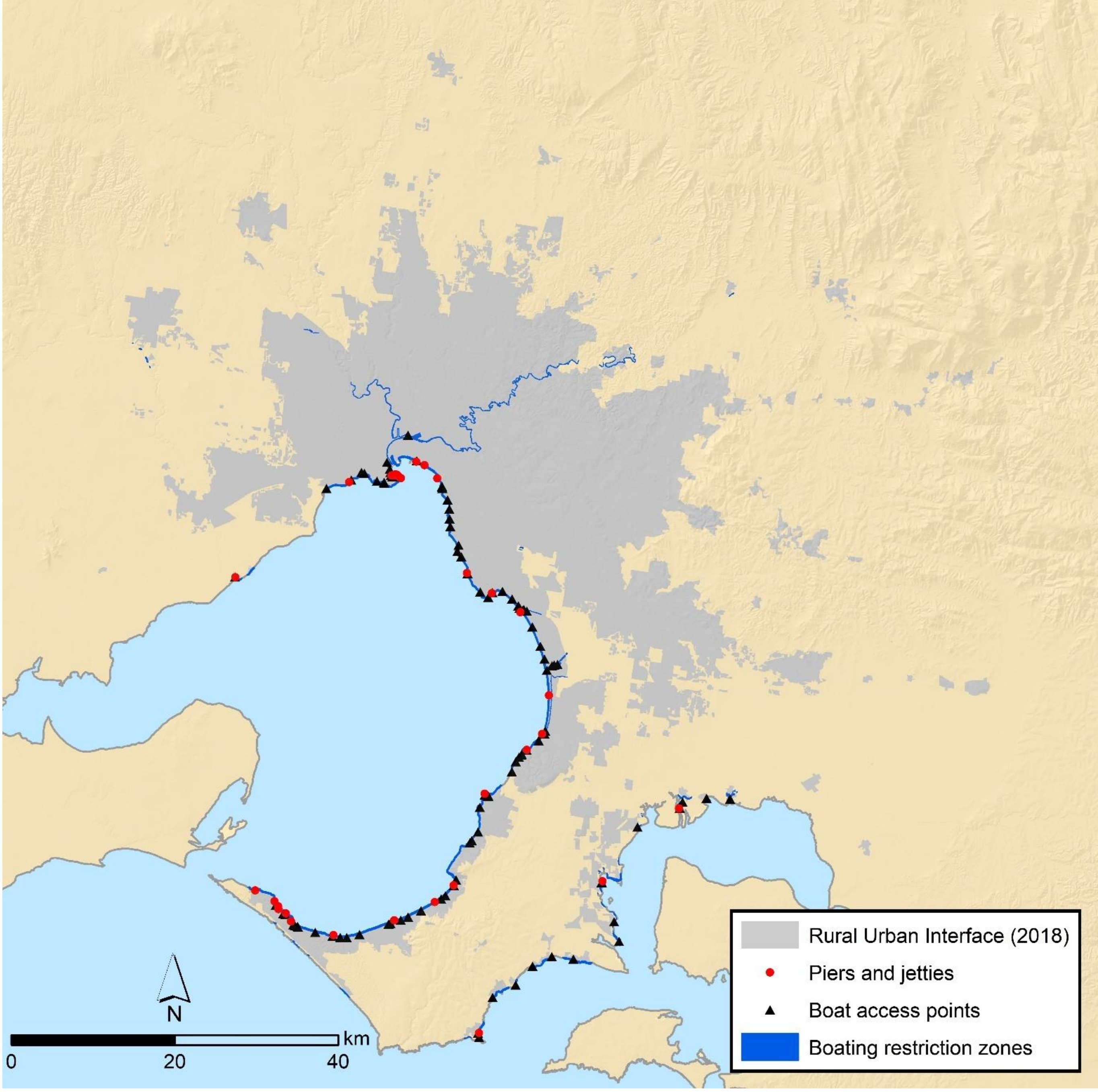

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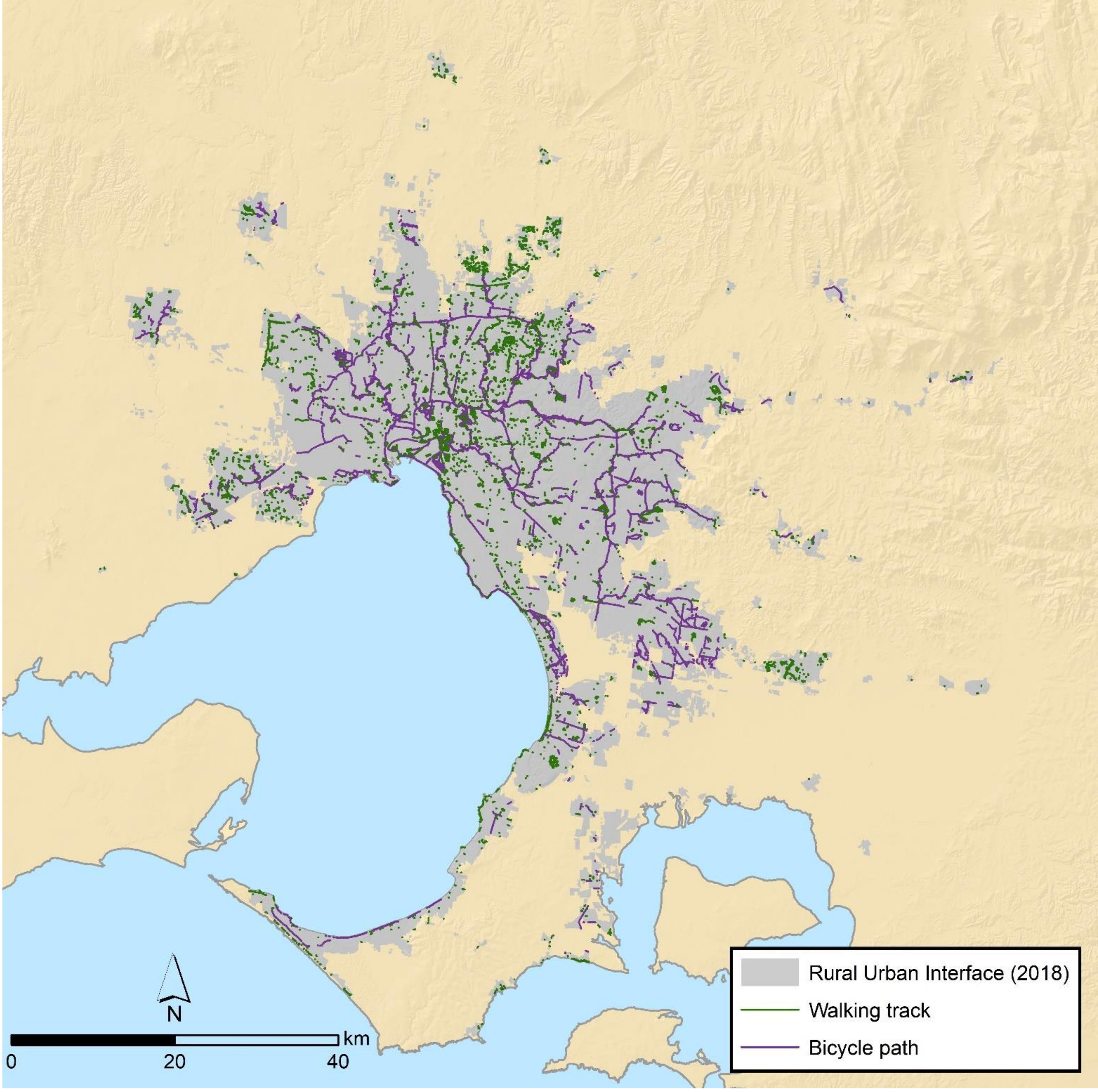
Figure 3.2.17. Walking tracks and bicycle paths (DELWP, 2017)



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3.2.3. Discussion

Key insights from the information compiled in the ecosystem condition account are:

- Native vegetation condition scores (measured from 0-100) (DELWP 2017) across the study area generally reflect the very high level of vegetation disturbance and average 8 out of 100 for the Melbourne EEA area. Private land within the study area scores very low (7) whilst public land has a slightly higher mean score (27). National parks (67) within the study area have relatively high scores however only make up 0.3 per cent of the study area (see Figure 3.2.1. and Table 3.2.3.). These figures highlight the level of native vegetation condition degradation outside of public land conservation areas and the importance of such areas in protecting the provision of ecosystem services.

- Habitat importance for threatened species is measured using 'Strategic Biodiversity Values' data (DELWP 2016c). The data combines information on important areas for threatened flora and fauna, levels of depletion, connectivity, vegetation types and condition to provide a view of relative biodiversity importance within the landscape (Figure 3.2.2. and Table 3.2.4.). The data tells a similar story to the native vegetation condition scores, with the very high level of disturbance to native vegetation being the main driver of low scores, averaging 24 out of 100 for the Melbourne EEA area. Private land within the study area has a very low mean score (22). National Parks house the most important habitats for threatened flora and fauna within the study area (mean score of 83). The importance of vegetation along hydrology corridor's, such as Dandenong Creek and Yarra and Maribyrnong Rivers, is clearly evident (Figure 3.2.2.) as an important provider of habitat services to threatened species. Many public land locations within the urban Melbourne EEA area however return low habitat importance scores as they are highly managed parks, recreational facilities or utility areas (such as golf courses, racecourses, airports, military facilities and graveyards) devoid of much native vegetation.

- Data from the Victorian Biodiversity Atlas (DELWP 2021) records the observation of 111 individual species of threatened flora and 103 individual species of threatened fauna located within the urban Melbourne EEA study area (Figures 3.2.3. and 3.2.4. and Tables 3.2.5. and 3.2.6.).

- Vegetation cover data was sourced from the Cooling and Greening Melbourne project (DELWP 2019a) and provides information on the proportion of grass, shrub and tree for ABS Statistical Area Level 1 (SA1) and Mesh Block levels. The data (Figure 3.2.5.) shows that vegetation cover across urban Melbourne varies significantly. The inner eastern suburbs have much higher proportions of tree coverage when compared to the newly developed areas of north western and south eastern Melbourne. This has implications for urban cooling capacity (refer to Section 4.6.).

- Above ground live biomass data across Victoria's public land areas has been created by the Victorian Forest Monitoring Program (DELWP 2018b) to inform Victoria's State of the Forest reporting (Figure 3.2.6.). The data is available from 2008 – 2017 on public land only and is the combination of long time series Landsat imagery combined with on ground forest plot measurements. Change in above ground biomass data over time provides information on the impact of major disturbances such as land clearing, droughts, bushfires and forest harvesting. The data for the study area shows a stable level of biomass from 2012 until 2017 which suggests limited major disturbances within the public land estate of urban Melbourne.

- Coastal acid sulphate soils (CASS) occur naturally across large parts of Victoria's coastline and if left undisturbed pose little risk to the environment and built assets. If disturbed however water draining from such sites can become highly corrosive damaging ecosystems and built assets. The Melbourne EEA study area contains 9,691 hectares of land susceptible to CASS (DJPR 2003) (Figure 3.2.7.). The Victorian Coast Acid Sulphate Soils strategy (DELWP 2009) helps landowners and land/water managers to avoid disturbing CASS. Undisturbed natural environments provide soil regulation ecosystem services protecting built assets and the environment from

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CASS.

- 2,474 hectares of land within the urban Melbourne EEA study area is classified as highly susceptible to landslide (DJPR and A.Miner 2017). The highest risk locations are concentrated around the Hastings area which comprises just 1.3 per cent of the total urban Melbourne EEA study area (Figure 3.2.7.). Slopes cleared of native vegetation are generally more susceptible to landslide due to reduced root density and depth resulting in less cohesive strength.

- The Victorian Index of Stream Condition (ISC) (DELWP 2010) brings together data from a variety of sources to give a detailed overview of river and stream condition. The ISC is made up of five sub-indices: hydrology, streamside zone, physical form, water quality and aquatic life. The 2010 ISC data shows that within the urban Melbourne EEA study area 81 per cent of the streams and rivers were in poor to very poor condition, 19 per cent in moderate condition and no streams were in good or excellent condition. The mean urban Melbourne EEA study area 2010 ISC score was 6 out of 50 (see Figure 3.2.8. and Table 3.2.8.).

- The Victorian Index of Estuary Condition (IEC) (DELWP 2021b) assesses five themes to give an overall score: physical form, hydrology, water quality and fish. Each theme contains multiple measurements. The 2021 IEC data shows that of the 19 estuaries within the urban Melbourne EEA study area none were in good or excellent condition, 3 were in moderate condition, 11 were in poor condition and 5 were in very poor condition (see Figure 3.2.9.). These results reflect the high level of urbanisation within the estuary catchment areas and highlight the importance of natural ecosystems for their ability to provide a range of eco-system services that maintain estuary and waterway health.

- Within the urban Melbourne EEA study area there are 213 flood water retarding basins that collectively cover 986 hectares (Melbourne Water, 2019) (see Figure 3.2.10.). These basins are open space areas set aside to temporarily store stormwater runoff from urban areas during heavy rain, thus reducing flood impacts. Many of these basins are grassy areas that also provide recreational space whilst not inundated whereas some other basins hold water permanently providing important wetland habitat.

- The urban Melbourne EEA study area stored 5.5 million tonnes of carbon in 2019 (DISER 2021), the more heavily vegetated eastern suburbs and vegetated river corridor's providing the bulk of that storage (see Figure 3.2.11.).

- Light pollution is commonly expressed using the Bortle scale, a nine-level numeric scale that measures the night sky's brightness through visibility of celestial objects with level 1 being a true dark sky with no interference through to 9 being a typical inner city location where only the brightest stars are visible. The majority of the urban Melbourne EEA study area is class 7 with the Melbourne CBD class 9. The map shown on Figure 3.2.12. (Stare 2021) shows light pollution mapped by radiance which is measured in watts per square meter per steradian.

- Data showing the percentage of houses within 400 metres of open space (AUO, 2020) shows much variation across the urban Melbourne EEA study area (Figure 3.2.13.). Eastern, northern and far eastern Melbourne have relatively low access to open space with large areas displaying less than twenty percent of all houses within 400 meters of open space.

- Analysis of data from the Victorian Heritage Database (DELWP 2019c) shows that there are 907 recorded historic cultural heritage sites that wholly or partly intersect with open space within the urban Melbourne EEA study area (Figure 3.2.14.).

- The urban Melbourne EEA study area intersects with three Designated Water Supply Catchment areas totalling 73 hectares, all within the Greenvale Reservoir area (DELWP, 2018c). Designated Water Supply Catchment areas (formerly Proclaim Water Supply Catchments) are proclaimed under the Soil Conservation and Land

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Utilization Act, 1958 in conjunction with the Land Conservation Act, 1970. These areas are subject to a Land Use Determination or a Land Use Notice to regulate development and thus protect the quality of water inflows.

- The Ramsar convention on wetlands is an international treaty for the conservation and sustainable use of wetlands named after the Iranian city in which the convention was first was adopted in 1971. There are three Ramsar listed wetlands within or intersecting the urban Melbourne EEA study area (Edithvale-Seaford Wetlands, Port Phillip Bay {western shoreline} and Western Port. (DEE, 2017) (Figure 3.2.15.)

- Within or intersecting the urban Melbourne EEA study area there are 26 individually named National Parks or Nature Conservation Reserves totalling just over 600 hectares (Figure 3.2.15.). Nearly half of that area (246 hectares) are conserved grasslands.

- Within the urban Melbourne EEA study area there are 35 public piers and jetties (DELWP, 2020) providing recreational opportunities for fishing, swimming, site seeing, nature observation and boating (Figure 3.2.16.).

- Within the urban Melbourne EEA study area there are 101 public boat access points such as ramps, slipways and launches (DELWP, 2020) providing recreational opportunities for sailing and boating (Figure 3.2.16.).

- Within or immediately adjacent to the urban Melbourne EEA study area there are 77 individually classified boating restriction zones totalling approximately 3,659 hectares (DELWP, 2020) (Figure 3.2.16.). The boating restriction zones are prepared under the Marine Safety Act 2010 with the primary aim of providing a safe environment for recreational water users to protect from powered and non-powered boats.

- There are 894 kilometres of walking tracks and 1,107 kilometres of bicycle paths within the urban Melbourne EEA study area (DELWP 2021d), see Figure 3.2.17.

Including broader (socio-economic) metrics related to location, cultural assets, built assets, governance and management practices (in addition to conventional ecological metrics of ecosystem asset condition), is important from a policy / management perspective as it provides for an understanding of the underlying drivers of differences in ecosystem service provision across space (and time, if these metrics / the account were to be developed over multiple time periods) and to consider how opportunities to boost ecosystem service provision can be delivered in a way that does not reduce ecological integrity and/or provides for net gains in societal welfare (e.g. raised boardwalks for recreation etc).

The ecological, social and economic information in environmental-economic accounts need to be considered together to provide decision makers with a picture of the characteristics that are supporting ecosystem service provision within an area. Such information also serves as an evidence base for decision makers to consider how to boost net societal welfare in an area, including if the trade-offs associated with doing so are acceptable and if certain constraints might be appropriate (beyond existing regulatory constraints).

For example, consideration might be given to whether it is appropriate to add new access footpaths to an area in an environmentally sensitive way so that people can enjoy recreational activities in the area (i.e. boost recreational visitation). A strong sustainability argument might lead to an assessment where no trade-offs are allowed in a geographic area such that additional recreational access (as measured through increased number of paths etc in the condition account and visitation in the physical / monetary accounts) can only be granted if certain ecological outcomes can be sustained (as measured in the condition account over time). Alternatively, a weak(-er) sustainability argument might allow some loss of biodiversity (as measured in the condition account over time) so long as net societal welfare increases due to the additional recreational visits (bearing in mind that there is no point in putting in new access paths if this will degrade the habitat / biodiversity to an extent where recreational visits would not be boosted / boosted sufficiently to lead to net gains in welfare).

4. Flow accounts

The SEEA EEA flow accounts focus on measuring and reporting on the contribution of the environment to the economy and society via ecosystem services, specifically:

a) Quantification of ecosystem services in physical terms: the metrics used to estimate the physical flows of ecosystem services in the reviewed assessments depend on the type of service as follows:

- Provisioning services are measured through physical output such as kilograms of food.
- Regulating services are measured through reductions in environmental harm such as the moderation of extreme temperatures (measured through urban cooling effect of green-blue infrastructure) and global climate change (measured through carbon sequestration and storage).
- Cultural services are measured through number of interactions such as recreational visit numbers.

b) Valuation of ecosystem services in monetary terms: the reviewed studies use a mix of exchange and welfare values to monetise ($) the physical provision of ecosystem services. In order to satisfy the requirements of the SEEA-EA and also be useful for informing government decision-making, the urban Melbourne EEA will develop estimates of exchange values (in order to develop SEEA-EA compliant environmental-economic account) alongside welfare values (for informing policy decisions). Irrespective of the method used to value ecosystem services, economic input costs (including labour, produced capital and intermediate inputs) need to be deducted to arrive at the value of an ecosystem service (UN, 2020e).

The reviewed assessments also estimate the socio-economic impact of ecosystem service provision where this is necessary for monetary valuation. There is not a dedicated account within the SEEA guidance (UN et al, 2012), but this could be usefully reported as an additional flow account.[15] Such "socio-economic" impacts typically estimate the population affected by regulating services through metrics such as:

- Population exposed;
- Quality adjusted life years (QALY's);
- Change in morbidity incidence; and
- Change in mortality incidence.

Further detail on the approaches taken to quantify and monetise the physical provision and of ecosystem services in the literature are provided in Annex 10 and 11 respectively.

The remainder of this section summarises the methodologies taken to quantify and value the seven[16] prioritised ecosystem services within the assessment boundary for the urban Melbourne EEA based on the data and methods used in the sources identified. This includes a description of how the urban Melbourne EEA captures the capacity of ecosystem assets in the region to provide an additional two[17] ecosystem services.

[15] This point is mentioned in SEEA Environmental-economic accounting (SEEA EA) Final draft: 9.5.2 Methods for incorporating spatial variation in prices (pers. comm. Jonathan Khoo, ABS).
[16] Air filtration; Amenity (bundle of ecosystem services); Education; Biomass provision - Food; Global climate regulation; Local climate regulation and Recreation: passive & active (health).
[17] Cultural value - heritage and knowledge; Existence / Option value.

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4.1. Air filtration

Population exposure to common air pollutants such as sulphur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3), and fine particulate matter (PM2.5 and PM10) are associated with a range of adverse human health outcomes. There is a large body of evidence that shows a clear association between increases in PM2.5 exposure and effects on respiratory and cardiovascular conditions as well as premature mortality (WHO 2016). Exposure to PM10, SO_2 and NO_2 has also been found to exacerbate cardiac conditions, asthma and other respiratory symptoms and diseases (EPA Victoria, 2018).

Vegetation removes pollutant particles from the air through pollutant deposition onto leaves and branches as well as absorption through stomata (Vos et al. 2012). The effect of this regulating ecosystem service is to improve air quality by reducing atmospheric pollutant concentrations. This benefits communities by reducing exposure to harmful pollutants which in turn improves health outcomes as well as reducing smog episodes which improve visual amenity (relative to a situation where there was no vegetation).

Figure 4.1.1. sets out the logic chain linking the ecological functioning of urban ecosystem assets to the socio-economic benefits provided (note not all of these are mutually exclusive). As the figure shows, the socio-economic benefits provided by urban vegetation in terms of absorbing pollutants and reducing the exposure of people, is determined by a number of factors, such as the ambient pollution concentrations, extent, type (i.e. species) and location of vegetation as well as precipitation, and other meteorological variables and chemical interactions (eftec, 2017; Fairman et al. 2010).

The location of vegetation is an important determinant of the amount and value of air quality regulation or 'purification' it provides, with the value of health benefits being found to be disproportionately greater in urban environments (eftec, 2017) because the amount of service provided is dependent on:

– Ambient air quality**:** urban areas tend to have higher levels of pollution, meaning a given amount and type of vegetation could remove more pollutants in an urban area than in a rural area;

– Interactions across space: urban green and blue space reduces air pollution concentrations in neighbouring areas outside of the urban extent (i.e. by intercepting it before it reaches these areas), thereby providing benefits outside of the urban area;

– The amount and type of vegetation**:** urban areas tend to have less vegetation per hectare than rural areas. This scarcity, combined with considerable local pollution sources, contributes to lower ambient air quality and a higher relative value of pollution mitigation in urban areas. Deposition velocities vary across vegetation/land cover types; and

– Population densities: the total benefit being delivered by vegetation removing one tonne of pollution is higher in areas of high population density (i.e. urban areas). This is because more people benefit from improvements in air quality.

Perversely, some studies have shown that certain types of vegetation can result in "ecosystem dis-services" (which are not covered within this account, but could be considered in future work) through the:

– Emission of volatile organic compounds which can increase concentrations of fine particulates and ozone (The Clean Air and Urban Landscapes Hub 2019); and

– Existence of urban vegetation in street canyons can obstruct wind flow, reducing ventilation which in turn can lead to higher pollutant concentrations (Vos et al. 2012).

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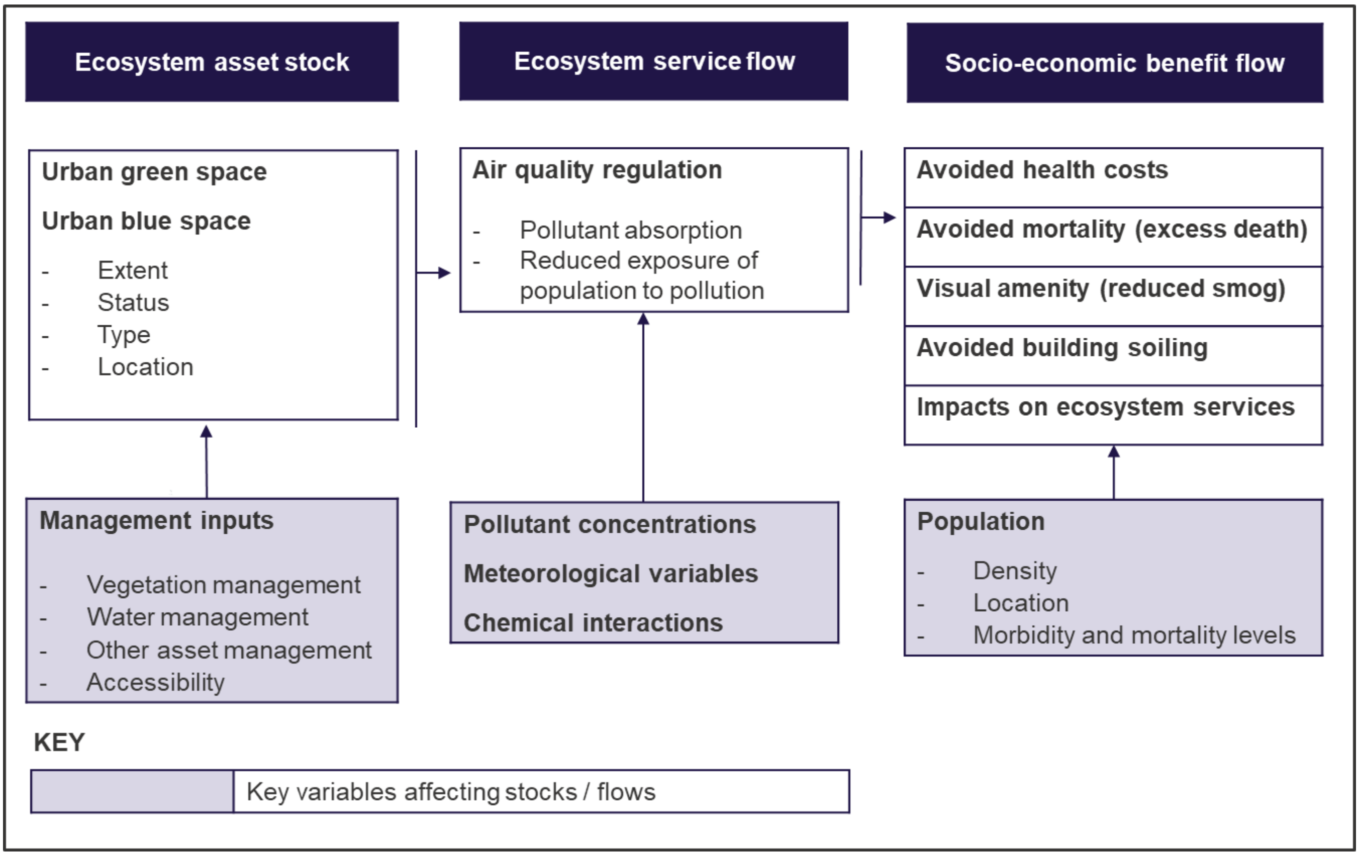
Consequently, there is a large degree of variability in, and a number of factors that determine, the extent of pollution that is removed by urban vegetation.

Figure 4.1.1. Illustrative logic chain for air filtration service of green infrastructure



For the purpose of this assessment, the focus is on estimating the value of urban ecosystem assets' air quality regulating service in terms of avoided incidence of ill-health (morbidity) and deaths (mortality) only.

4.1.1. Physical provision of air filtration

4.1.1.1. Methodology

The literature review found that a range of different approaches to estimating the air quality regulating service of vegetation are adopted globally. While the science is fairly robust, different models and different approaches may produce widely varying estimates of air pollution removal by ecosystems (eftec et al, 2017). There is a complexity to the service which makes estimating changes in pollutant levels challenging. There is a trade-off inherent between the accuracy of incorporating atmospheric transport and pollutant interactions at national scale, and the fine detail required to populate information about the type and location of vegetation on the ground (eftec et al, 2017).

Based on the literature review (see Annex 10, Section A10.1), the approach to estimate air quality regulation service is to estimate pollutant capture per tree (tonne/tree/year) within the urban Melbourne EEA boundary based on the estimates used in the Jayasooriya et al. (2017) study which used the Australian compatible version of iTree Eco. This version of iTree Eco was introduced in 2011 to include integrated air pollution and local weather data for Victoria and Melbourne specific parameters for input to the iTree Eco software. Pollutant capture per tree was estimated by Jayasooriya et al. (2017) for the following pollutants: NO_2, SO_2, PM10, CO, PM2.5 and O_3. The study estimated a single tree would remove 0.0260 kgs of NO_2, 0.0084 kgs of SO_2, 0.0859 kgs of PM10, 0.0034 kgs of CO, 0.0027 kgs of PM2.5 and 0.0939 kgs of O_3 annually.

These Melbourne specific pollutant capture figures per tree from Jayasooriya et al. (2017) were applied to the number of city / street trees within the assessment boundary, estimated at around 6.9 million trees[18], based on data for Melbourne from the Vicmap Vegetation – Tree Urban dataset (DELWP, 2021).[19]

Figure 4.1.2. shows the distribution of urban trees within the assessment boundary, based on the Vicmap Vegetation – Tree Urban dataset (DELWP, 2021), noting that this dataset does not completely cover the assessment area.

Figure 4.1.2. Urban trees within the urban Melbourne EEA boundary

[18] This figure of 6,856,568 trees is based on the coverage within the entire assessment area, while the figure reported in Table 3.2 and elsewhere in the report of 5.2 million represents only those trees within built up areas.

[19] The Tree Urban dataset did not completely cover the assessment area (mostly in the far eastern extent of the rural-urban interface), so an adjustment was made using the average density for the covered region, which was then applied to the area of the uncovered region in the assessment area.

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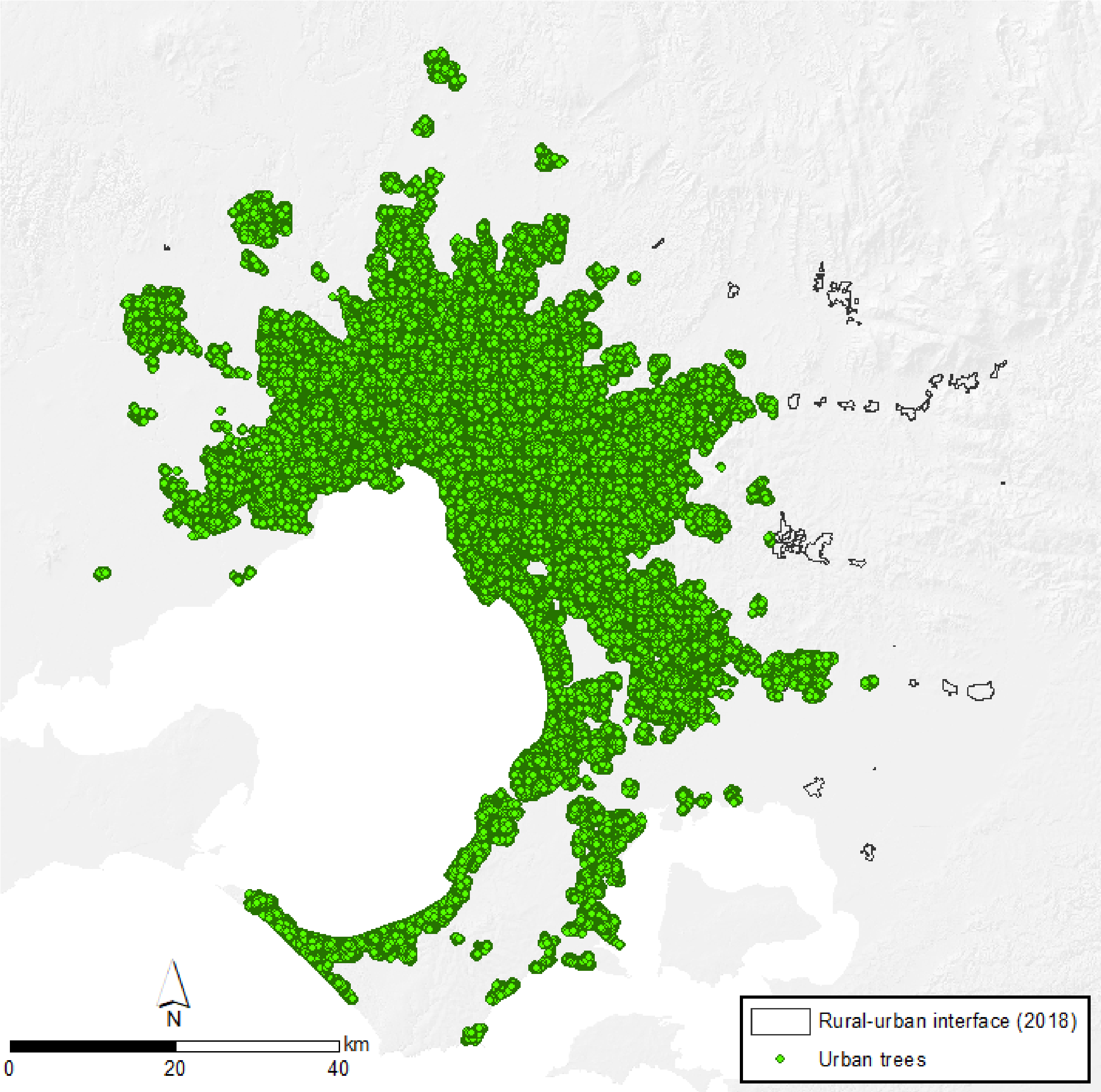

4.1.1.2. Results

The volume of pollutants removed by the estimated 6.9 million urban trees across Melbourne is estimated for the following pollutants: NO_2, SO_2, PM10, CO, PM2.5 and O_3,, see Table 4.1.1.

Table 4.1.1. Estimated annual pollutants removed by urban trees in Melbourne

Pollutant	Estimated physical value	Metric	Year	Source
NO_2	177.96	Tonnes / yr	2019/20	DELWP (2021), Jayasooriya et al. (2017)
SO_2	57.57			
$PM_{2.5}$	18.32			
PM_{10}	588.83			
O_3	643.78			
CO	23.55			

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Table 4.1.2 summarises the uncertainty associated with these results and shows that there is a high level of uncertainty associated with the estimates of the physical provision of air quality regulation by urban trees in Melbourne. This is in part due to the static approach to estimating air quality regulation from urban vegetation from iTree Eco modelling, with limited metrological and chemical interactions, as well as the accuracy of the model which the Vicmap Vegetation Tree Urban database is based on.

Table 4.1.2. Uncertainty assessment - physical provision of air quality regulation

	Uncertainty in…		
	Evidence	**Assumptions**	**Total**
Explanation	- Reliant upon iTree Eco's modelling of air quality regulation by vegetation in Melbourne. - This is a static approach to estimating air quality regulation from urban vegetation, with limited metrological and chemical interactions. - The Vicmap Vegetation Tree Urban dataset was used to estimate the number of trees in the urban area, however the dataset does not cover the entire assessment area (approximately 1.7 per cent of the total area was not covered by the urban tree extent). - The Vicmap Vegetation Tree Urban dataset is based on a model with accuracy of 78%. The model does not identify every tree and has known issues identifying trees in a dense canopy where many trees overlap.	- Assumes that the Jayasooriya et al. (2017) estimates for a 250 hectare case study area in the west of Melbourne are relevant to all of Melbourne. - Assumes that the regions of the assessment area not covered by the urban tree database extent are of similar tree density as the remainder of the assessment area.	High
Rating	3	2	6

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4.1.2. Monetary value of air filtration

4.1.2.1. Methodology

Based on the reviewed literature from around the world, numerous studies have adopted an "impact pathway" approach to estimating the monetary value of health outcomes associated with changes in population exposure to air pollution.

An impact pathway approach is a systematic method for identifying and tracing the effects of air pollution, from changes in emissions through to impacts on outcomes that society values (e.g. reduced morbidity and mortality), producing 'damage costs' per tonne of pollutant or per unit change in the atmospheric concentration of the pollutant.

Impact pathways for specific countries or jurisdictions are generated using location-specific inputs and data such as air pollutant modelling, population densities, prevalent health risk assessments and health costs. This is a relatively complex approach which estimates damage costs per change in unit exposure using dose-response functions, which require information on current mortality and morbidity data for a local geographic area (e.g. local government area) and the change in pollutant exposure of the receiving population due to vegetation (eftec et al, 2017 Jones et al, 2019).

Based on the literature reviewed, a full impact pathway approach for Australia (i.e. including economic valuation) has not been developed and so there are no location-specific damage costs for Australia/Victoria. The Australian studies reviewed instead use average damage costs (i.e. for a defined geographic area) derived in other locations and adjust these for the Australian context (see Annex 11, Section A11.1) to estimate the health impacts and associated economic value of pollution removal by vegetation.

The value of air quality regulation (pollutant capture) by vegetation within urban Melbourne is estimated using figures from:

– Parry et al. (2014) of $12,940 per tonne SO_2, $2,630 per tonne NO_2, and $334,060 per tonne PM2.5[20] based on a study which estimates the damage costs for ground level air pollution in Australia, specifically related to changes in mortality. The study uses the OECD Value of a Statistical Life, this is estimated for several countries, including Australia.
– PAE Holmes (2013) of $227,540 per tonne of PM2.5[21] which is based on adjusting UK specific estimates (Defra, 2013) of damage costs related to morbidity and mortality, to the Australian context using value transfer technique. The UK values are based on the Value of a Life Year.

The use of these two sources means that a range will be provided for the economic value of PM2.5 and that the valuation of the air quality regulation service provided by trees in Melbourne will not include all of the pollutants that are estimated in the physical flow account as there are no Australia specific estimates of the value of damage costs for PM10, CO or O_3.

A variety of sources have been drawn in this Melbourne EEA to estimate the value of ecosystem services. In the case of avoided mortality costs, the value-of-statistical life methodology has been adopted in two cases, using different sources which leads to different values for the same outcome. Specifically, the OECD Value of a Statistical Life estimates of $5.2 million in 2010 from Parry et al (2014) are used to estimate the value of air quality regulation

[20] Converted from 2010 USD to Australian dollars from US$9,220 per tonne SO2, US$1,873 per tonne NO2, and US$238,099 per tonne PM2.5 using average AUD/USD exchange rate in 2009/10 of $0.88 (Reserve Bank of Australia, Historical Exchange Rates) and updated to 2021 using a CPI adjustment from June 2010 to June 2021 for All groups CPI, Australia.
[21] Updated to 2021 Australian dollars from $190,000 using CPI adjustment from June 2011 to June 2021 for All groups CPI, Australia.

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and the Australian Department of PM and Cabinet (2019) values of $4.9 million per incident in 2019 are used to estimate the value of urban cooling. In order to ensure consistency throughout the analysis used for this Melbourne EEA, these values have been reconciled by adjusting the Parry et al (2014) values to align with the Australian Department of PM and Cabinet (2019) values as follows:

- Converting OECD VSL values in Parry et al from 2010 USD to 2010 AUD. This gives a VSL of $4.5 million in 2010
- Uprating the OECD Parry et al VSL value in 2010 AUD terms and the Australian Department of PM and Cabinet (2019) VSL value in 2019 AUD terms for inflation to 2021 AUD. This gives a value of $5.6 million in 2021 AUD for the VSL from Parry et al and a value of $5.1 million for the VSL from the Australian Department of PM and Cabinet.
- Estimating the ratio of VSL given by the OECD and the Australian Department of PM and Cabinet in 2021 terms.
- Multiply the OECD VSL 2021 figure by the ratio of the OECD and the Australian Department of PM and Cabinet VSL estimates.

4.1.2.2. Results

The monetary value of pollutants removed by urban trees in a year has been estimated for NO_2, SO_2 and $PM_{2.5}$. These estimates are shown in table 4.1.3.

Table 4.1.3 Monetary value of air quality regulation from urban trees in urban Melbourne

Pollutant	Estimated monetary value	Metric	Year	Source
NO_2	$0.4m	$m/yr	2019/20	DELWP (2021), Parry et al. (2014), PAE Holmes (2013)
SO_2	$0.6m			
$PM_{2.5}$	$5.0m - $5.3m			
Total	**$6.0m to $6.4m**			

Table 4.1.4 summarises the uncertainty associated with these results and shows that there is a high level of uncertainty associated with the estimates of the monetary value of air quality regulation. This is in part due to the reliance on estimated values from Holmes (2013) and Parry et al (2014), which were not developed specially for urban Melbourne, as well as the accuracy of the model which the Vicmap Vegetation Tree Urban database is based on.

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Table 4.1.4 Uncertainty assessment - monetary value of air quality regulation

	Uncertainty in…		
	Evidence	**Assumptions**	**Total**
Explanation	- Reliant upon the underlying physical estimates - see Table 4.1.2 for uncertainty associated with these. - Reliant upon $ values of health impacts caused by pollutants from two Australian specific sources - PAE Holmes (2013) and Parry et al (2014).	- Assumes that estimates from Parry et al. (2014) of health costs of pollution for all of Australia are relevant to urban Melbourne. - Assumes that the estimates from PAE Homes (2013) which were based on estimates from the UK and then adjusted using value transfer technique will be relevant to urban Melbourne.	High
Rating	3	3	9

4.1.3. Supply and use of air filtration service

The users (beneficiaries) of the air quality regulation ecosystem service provided by street trees in urban Melbourne are the individuals/households who benefit from avoided morbidity and mortality associated with air pollution, see Table 4.1.5.

Table 4.1.5. Supply and use table for air quality regulation from urban Melbourne ecosystem assets in 2019

		Metric		Household	Gov.	Industry	Ecosystem
							Urban trees
Air quality regulation	Supply	Tonnes / yr	NO_2				178
			SO_2				58
			PM2.5				18
			PM10				589
			O_3				644
			CO				24
	Use	Tonnes / yr	NO_2	178			
			SO_2	58			
			PM2.5	18			
			PM10	589			
			O_3	644			
			CO	24			
Air quality regulation	Supply	$ AUD (2021) / yr					$6.0m - $6.4m
	Use	$ AUD (2021) / yr		$6.0m - $6.4m			

4.1.4. Discussion

The analysis for the physical provision of air quality regulation estimates the annual volume of specific air pollutants that is captured by urban trees in Melbourne. The results should be interpreted as indicative, noting the underlying limitations of iTree Eco and the application of the Jayasooriya et al. (2017) specific estimates of iTree Eco parameters (which are based on a 250 hectare case study area in the west of Melbourne) to all of Melbourne. This is a static approach that combines the fine detail (high resolution) of spatial information on trees across Melbourne, with limited metrological and chemical interactions (compared to (for example) the EMEP4UK modelling undertaken by eftec et al (2017) for the UK urban environmental-economic account).

The analysis for the monetary account provides a partial estimate of the value of the socio-economic benefits provided by the removal of harmful air pollutants by urban trees in Melbourne in terms of avoided morbidity and mortality costs. This is estimated to be between $6.0m to $6.4m annually. This is a partial figure because it only estimates the value of NO_2, SO_2 and $PM_{2.5}$ removal, while other harmful particulates are also absorbed by the trees. While this may be an underestimate, it is likely it captures most of the benefit because Parry et al (2014) note that the main cause of mortality risk from pollutants comes from $PM_{2.5}$.

See Section 5.4 for consideration of how the approach to estimating the physical and monetary provision of air quality regulation by urban vegetation in Melbourne could be refined in the future.

4.2. Amenity

The existence of green space is an important aspect of the liveability of an area. Liveability in this context is derived from the “bundle of ecosystem services” provided by green spaces and is often referred to as the “amenity” value of green infrastructure (DELWP, 2015).

The method that is typically adopted to capture amenity value is through the uplift in value or “price premium” associated with properties that are in close proximity to well-planned and managed parks, gardens and squares. This economic valuation technique is a revealed preference approach known as the hedonic pricing method. There are extensive examples in the economic valuation literature of its adoption to estimate the price premium associated with the presence of and access to greenspace, taking into consideration other factors that are thought to affect the price such as house features, building age, transport, schools (DELWP, 2015). This method indirectly estimates amenity value by observing how prices in another related market (i.e. housing) changes with proximity to ecosystem assets. Because amenity values are estimated based on housing price premiums, they represent the value of ecosystem assets to residents / property owners only (and not to other users of urban green space).

DELWP and Parks Victoria (2015) use a hedonic pricing approach to estimate the amenity value of urban and peri-urban parks in Melbourne to be between $21m and $28m a year. This higher “willingness to pay” for property in close proximity to green space is, in part, an expression of the value of the “bundle of ecosystem services” enjoyed by residents. It is not possible to be specific about which ecosystem services are captured through a hedonic pricing method. It could be postulated that the buyers of properties must be aware of the services (positive externalities) provided by green infrastructure for those services to be reflected in property prices. The UK Office for National Statistics (ONS) “work on the assumption that the majority of the value captured (in housing price premiums) is that from cultural services, such as recreation and attractive views, rather than regulating services such as carbon regulation and temperature regulation which people are less likely to be aware of” (ONS, 2018).

Identifying the bundle of ecosystem services that amenity value is assumed to capture is important in order to avoid any double counting of value in environmental-economic accounts. The amenity valuation may capture some (or none, or all) of the value of the other ecosystem services that are assessed for this urban Melbourne EEA, as well

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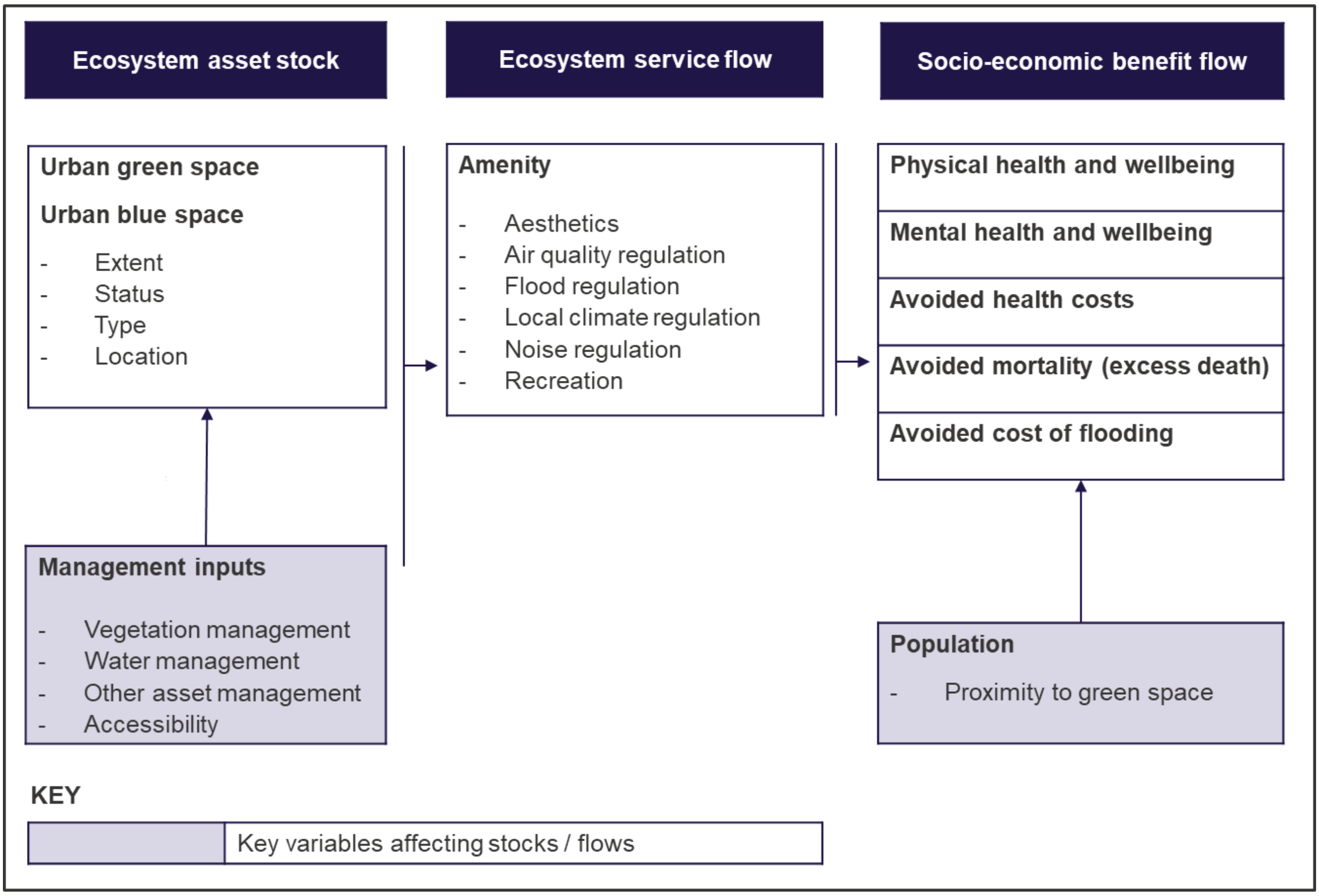
as some of the value of other locally specific ecosystem services such as noise regulation, aesthetics etc. that are not captured in this account.
For the purpose of this assessment, the bundle of ecosystem services that amenity value is assumed to include, are those that improve the liveability of an area (i.e. those ecosystem services that are enjoyed as a result of residential proximity to green space) which, given the scope of ecosystem services included in this assessment, include recreation, local climate regulation, air quality regulation, food and educational (school) ecosystem services. In order to avoid double counting, the value of these ecosystem services are not added to the estimated amenity values when aggregating the monetary values for this urban Melbourne EEA.

This means that the value of the global climate regulation service that is provided by parks is assumed to have no effect on the value of nearby residential properties (i.e. the capture and storage of carbon by urban ecosystem assets that are in close proximity to a residence is not assumed to be perceived by homeowners to directly improve the liveability of an area and so is not captured in the hedonic valuation of amenity. This is primarily because the capture and storage of carbon is a global public good which means that the location of sequestration and storage has no effect on the global carbon balance and everyone in society benefits from this, irrespective of the location of their residence). The possible link between the local provision of other ecosystem services (e.g. food production and education) and nearby house prices based on improved liveability of an area is tenuous, but these are included in order to be sure we avoid any double counting. Further work could be done to reach a consensus on the definition of amenity value in urban areas.

Figure 4.2.1. sets out the logic chain linking the ecological functioning of urban ecosystem assets to the socio-economic benefits provided (note not all of these are mutually exclusive).

Figure 4.2.1. Illustrative logic chain for amenity service from green-blue infrastructure



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4.2.1. Physical provision of amenity

Estimates of the amenity value of green space from the literature are focused solely on monetary valuation rather than physical provision. This partly reflects the method that is typically used to value amenity (i.e. hedonic pricing) which relies on estimating price premiums associated with residential buildings in close proximity to green space. It also reflects that amenity value is an expression of the value of a "bundle of ecosystem services" and so there is not a specific ecosystem service output that is produced (unlike other ecosystem services where the physical provision of the service is quantified and then subsequently valued). One metric that is of relevance in determining the capacity of ecosystem assets to deliver amenity value is the proximity of households to urban green space (see the condition account, Section 3.2.2)

4.2.2. Monetary value of amenity

4.2.2.1. Methodology

A review of literature found numerous studies estimating the value of amenity provided by current urban ecosystem assets in Melbourne/Victoria using the hedonic price method (i.e. the increased real estate values associated with urban ecosystem assets), see Annex 11, Section A11.2. Many of the studies reviewed use value transfer to apply estimates from other studies / geographic areas (i.e. Mahmoudi et al. (2013) in Adelaide; Rossetti (2013) for all of Australia; and Thomy et al. (2016) in NSW) to Melbourne and these are excluded from consideration for this urban Melbourne EEA on this basis.

The Infrastructure Victoria and Aither (2018) and Cooper et al. (2016) studies are the only identified studies to have used primary research for study areas within Melbourne. The Cooper et al. (2016) would be challenging to use to value of the current condition of Melbourne waterways in a Melbourne urban environmental-economic account as these are marginal values (willingness to pay for a per cent improvement in one of four scenarios). Consideration of amenity of value of blue space is therefore ruled out for further consideration in this urban Melbourne EEA.

The approach to valuing the amenity benefits of urban ecosystem assets in Melbourne uses *The Victorian Amenity Valuation Tool for Cost Benefit Practitioners* (henceforth the "Amenity Tool") produced by Infrastructure Victoria and Aither (2018). The main justification for the use of the Amenity Tool is that it has been developed specifically for Melbourne (and the wider State of Victoria) using recent primary data collection (2016). Aither and Infrastructure Victoria used the hedonic pricing method to estimate the value ($) of parks through residents' willingness to pay to live closer to particular types of parks using property prices. Their study provides estimates of amenity value of four major types of parks within Victoria using hedonic regression. In Melbourne, it is the metropolitan parks and sport and recreational parks that provide positive amenity, while some parks are considered dis-amenities with positive distance elasticities, specifically community and cultural parks, reserves and other parks. The focus on this assessment will be on only those parks which provide positive amenity (metropolitan parks and sports and recreational parks).

The key challenge in applying the Amenity Tool to develop estimates for incorporation into the environmental-economic account for Melbourne is that the urban ecosystem assessment requires an estimate of the *total* amenity value ($) of existing parks across metropolitan Melbourne given the actual number of substitute sites within a LGA, whereas the Amenity Tool focuses on the *marginal* value of adding a hypothetical park given a user defined number of substitutes (up to 25) within a defined LGA. Discussions with an author of the Amenity Tool suggested that it could be applied to estimate a total value for use in environmental-economic accounting and advice was provided to the study team on an appropriate methodology (pers. comm. David Prentice, Infrastructure Victoria). Table 4.2.1. sets out the step-by-step methodology that was adopted to estimate the amenity value ($) of parks across metropolitan Melbourne using the Amenity Tool. The estimated value of existing parks within the assessment boundary is based

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on 2016 house price data, uprated to 2021 dollars using the inflation rate for new dwelling purchases by owner-occupiers[22].

[22] Updated to 2021 dollars using CPI adjustment from June 2016 to June 2021 for New dwelling purchase by owner-occupiers, Melbourne.

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Table 4.2.1. Proposed method to estimate total value of amenity from Melbourne's parks using the Amenity Tool developed by Infrastructure Victoria and Aither (2018)

Step	Method	Justification
1. Choose one of the two amenity types (metropolitan parks and sport and recreational parks) and a metropolitan LGA	Input to Amenity Tool	This will enable the results to be tailored to different amenity types and to different LGAs (of which there are 32 within the urban assessment boundary)
2. Once the LGA has been selected in the Amenity Tool, choose the 'Custom' selection in the drop-down menu	Input to Amenity Tool	This will ensure that the model is based only on the current population of the chosen LGA, rather than estimating the values to households living in expected future residential developments for the next thirty years on currently non-residential land
3. Calculate total area of LGA (km^2)	GIS software using spatial data for Victorian LGAs[23]	This will enable the proportion of the chosen amenity type within the LGA to be determined
4. Calculate total <u>area</u> of chosen amenity type within LGA (km^2)	GIS software using spatial data for *Public Land Management (PLM25)*[24] and *Geomark Polygon*[25], which includes spatial data for the amenity types	This will enable the proportion and average size of the chosen amenity type within the LGA to be determined
5. Calculate total <u>number</u> of chosen amenity type within LGA (no.)		This will enable the average size of the chosen amenity type within the LGA to be determined
6. Calculate the <u>proportion</u> of chosen amenity type within the LGA (%)	= Step 4 / Step 3	This will enable the proportion of the chosen amenity type within a radius (set in the Amenity Tool) to be determined
7. Calculate the <u>average size</u> of chosen amenity type within the LGA (km^2)	= Step 4 / Step 5	This will enable the average number of the chosen amenity type within a radius (set in the Amenity Tool) to be determined
8. Using the area of a circle, estimate the area ("A" km^2) of chosen amenity type within selected radius ("x") [26]	= "A" km^2 * Step 6 ("A" = $\pi * x^2$)	As per Step 5
9. Estimate the average number of chosen amenity type within the selected radius (no.)	= Step 8 / Step 7	As per Step 6
10. Estimate the number of substitute amenity types (no.)	= Step 9 - 1 Input to Amenity Tool	The Amenity Tool estimates the value of an additional amenity type given the number of substitutes located within the defined radius
11. Estimate an <u>average value</u> of the chosen amenity type in the LGA ($)	Calculate value in Amenity Tool	This will enable the total value of all the chosen amenity types within the LGA to be estimated
12. Estimate <u>total average value</u> of chosen amenity types within the LGA ($)	= Step 11 * Step 5	As per Step 10
13. Uprate estimated value to current prices	= Step 12 * rate of inflation	This will allow the values to be assessed in current (2021) prices
14. Estimate annualised values from the asset values (capitalised value) using an equivalent annual cost calculation with an appropriate discount rate (as per VPS guidance) and time horizon.	Calculate annualised values	The amenity tool will estimate the value of amenity as capitalised into asset prices (house values), this calculation converts this into an annual (flow) value for use in environmental-economic accounts.
15. Repeat above steps for remaining metropolitan LGAs	Steps 1-14	This will enable to total value of the chosen amenity across metropolitan Melbourne to be estimated
16. Estimate total value of the chosen amenity type for <u>metropolitan Melbourne</u> ($)	Add values from Step 15 for all 32 metropolitan LGAs	As per Step 15
17. Repeat above steps for each amenity type	Steps 1-16	This will enable the total value of all amenities across metropolitan Melbourne to be estimated

[23] https://data.gov.au/dataset/ds-dga-bdf92691-c6fe-42b9-a0e2-a4cd716fa811/distribution/dist-dga-b8d5d18b-5057-4fef-967d-d947df388b98/details?q=

[24] https://discover.data.vic.gov.au/dataset/public-land-management-plm25

[25] https://discover.data.vic.gov.au/dataset/geomark-polygon

[26] The amenity tool requires the user to select a radius for the analysis (within which number of substitute sites is input) between 500m and 5km. The study team suggests that the radius selected in the analysis is the maximum radius that will fit entirely within all LGA's in order to best reflect the amount of green space within each LGA.

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4.2.2.2. Results

Figure 4.2.2. shows the distribution of metropolitan parks and sports and recreation parks within the assessment boundary. The estimated value of amenity from existing parks within the assessment boundary is as follows:

– Metropolitan parks: The amenity value of 28 metropolitan parks in the urban Melbourne EEA is estimated to be $7.6 billion, with an annualised value of $0.5 billion per year, see Table 4.2.2. for more detail including a breakdown by LGA.

– Sports and recreation parks: The amenity value of over 1,300 sports and recreation facilities in urban Melbourne is estimated to be approximately $14 billion with an annualised value of $1 billion per year see Table 4.2.2. for more detail.

Figure 4.2.2. Metropolitan and sports and recreation parks across urban Melbourne

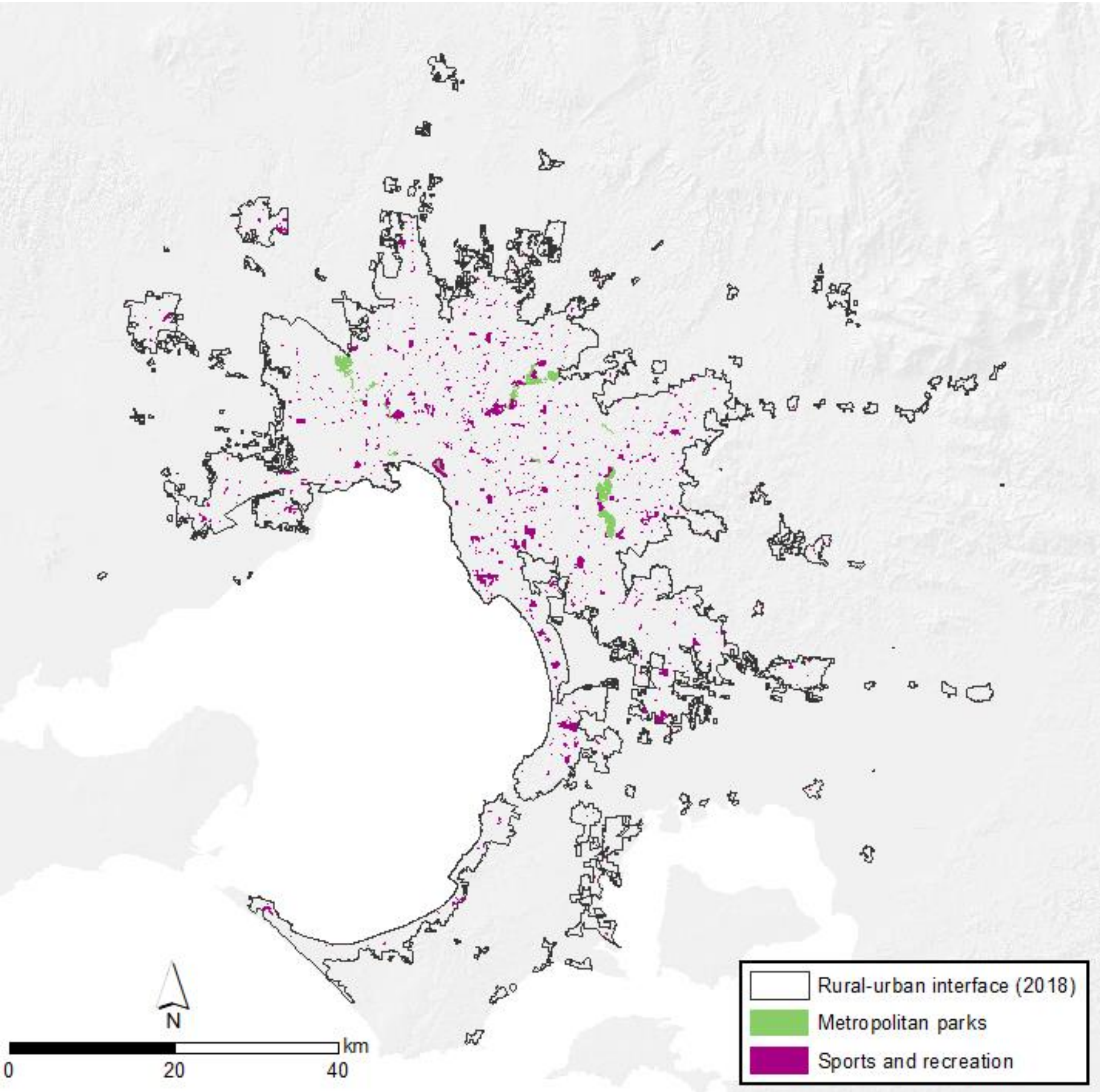

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Table 4.2.2. Estimated value of amenity from parks within the assessment boundary using the Amenity Tool developed by Infrastructure Victoria and Aither (2018)

LGA	Metropolitan parks		Sports and recreation parks	
	Total value ($m)	Annualised value ($m/yr)[27]	Total value ($m)	Annualised value ($m/yr)[28]
Banyule	$297m	$21m	$299m	$21m
Bayside	-	-	$430m	$30m
Boroondara	$966m	$68m	$985m	$69m
Brimbank	$62m	$4m	$290m	$20m
Cardinia	-	-	$89m	$6m
Casey	-	-	$592m	$42m
Darebin	$206m	$15m	$356m	$25m
Frankston	-	-	$197m	$14m
Glen Eira	-	-	$440m	$31m
Greater Dandenong	-	-	$274m	$19m
Hobsons Bay	$99m	$7m	$208m	$15m
Hume	-	-	$1,089m	$76m
Kingston	$121m	$9m	$350m	$25m
Knox	$77m	$5m	$298m	$21m
Manningham	$194m	$14m	$449m	$31m
Maribyrnong	$362m	$25m	$189m	$13m
Maroondah	$112m	$8m	$218m	$15m
Melbourne	$859m	$60m	$504m	$35m
Melton	-	-	$305m	$21m
Mitchell	-	-	$1m	$0.1m
Monash	$204m	$14m	$572m	$40m
Moonee Valley	$471m	$33m	$341m	$24m
Moreland	-	-	$368m	$26m
Mornington Peninsula	-	-	$1,770m	$124m
Nillumbik	$17m	$1m	$300m	$21m
Port Phillip	$1,674m	$117m	$675m	$47m
Stonnington			$795m	$56m

27 The annualised value is calculated using the Equivalent Annual Cost calculation, which converts the capitalised value of amenity (asset prices) into an annual (flow) value; r (discount rate) = 7 per cent, t (time periods) = 100 years.

28 The annualised value is calculated using the Equivalent Annual Cost calculation, which converts the capitalised value of amenity (asset prices) into an annual (flow) value; r (discount rate) = 7 per cent, t (time periods) = 100 years.

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LGA	Metropolitan parks		Sports and recreation parks	
	Total value ($m)	Annualised value ($m/yr)[27]	Total value ($m)	Annualised value ($m/yr)[28]
Whitehorse	$713m	$50m	$458m	$32m
Whittlesea	-	-	$870m	$61m
Wyndham	-	-	$425m	$30m
Yarra	$1,184m	$83m	$382m	$27m
Yarra Ranges	-	-	$128m	$9m
Total	**$7,620m**	**$534m**	**$14,645m**	**$1,026m**

Table 4.2.3. summarises the uncertainty associated with these results and shows that there is high level of uncertainty associated with the amenity value of parks in urban Melbourne. This is because the method used to estimate value does not account for the size, quality or unique characteristics of the assessed parks.

Table 4.2.3. Uncertainty assessment - monetary value of amenity

	Uncertainty in…		
	Evidence	Assumptions	Total
Explanation	– The estimates of amenity value of parks is based on price elasticities that are estimated using a hedonic pricing method from one Melbourne specific study by Aither and IV. – The Amenity Tool does not have the functionality to enable estimates of the amenity value of all ecosystem assets, including (for example) the value of living close to reserves and coastal areas (e.g. beaches) in metropolitan Melbourne. This is an area for further research.	– The Amenity Tool does not account for the size, quality or unique characteristics of the assessed parks. For example, Albert Park might be a particularly attractive Metropolitan Park but this will not be captured in the estimated value of Metropolitan Parks in the Port Phillip LGA. Instead, the estimate is implicitly based on the value to nearby residents of a Metropolitan Park in Port Phillip LGA with characteristics that are typical of Metropolitan Parks across the state (Aither, 2017). – The proposed approach involves averaging an estimated value across an LGA, so this method could potentially provide a balancing or averaging factor to the many different forms and sizes of amenity types present across Melbourne (e.g. averaging out the value of a large metro. park and a smaller local metro. park) – Values have been uprated from 2016 to 2021 dollars using the inflation rate for new dwelling purchase by owner-occupiers, however this is still likely to undervalue amenity as house prices in Melbourne have increased by a higher rate over the period.	High
Rating	3	3	9

4.2.3. Supply and use of amenity

The users (beneficiaries) of the amenity value of green spaces in urban Melbourne are the individuals/households who benefit from the bundle of ecosystem services that the amenity value comprises, see Table 4.2.4.

Table 4.2.4. Supply and use table for amenity value from urban Melbourne ecosystem assets

		Metric	Household	Government	Industry	Ecosystem	
						Metropolitan parks	Sports and recreation parks
Amenity	Supply	$ AUD (2021) / yr				$534m	$1,026m
	Use	$ AUD (2021) / yr	$1,560m	-	-	-	-

4.2.4. Discussion

The use of hedonic pricing method (rather than a welfare based approach) is consistent with the use of exchange value in SEEA. This approach indirectly values the ecosystem services provided by having access to green space using prices within the housing market. However, (as mentioned above) it is unclear precisely what "bundle of ecosystem services" are captured within this approach and caution needs to be used when using this "amenity" value alongside other estimates of the value of ecosystem services from urban ecosystem assets in Melbourne.

The estimated amenity value of metropolitan parks within the urban Melbourne EEA region is estimated to be $0.5 billion per year and $1 billion per year for sports and recreation parks. This value is a demonstration of residents' willingness to pay to live closer to these particular types of parks, which will in part be determined by their *ability* to pay. Thus, the estimated value of a particular park using this method is closely tied to the actual sale prices of houses in the surrounding area which will be determined by the wealth / income of property owners.

The interpretation of this value for policy decision making needs careful consideration to avoid the conclusion that society values parks more highly in affluent areas compared to less affluent areas. There are a number of reasons why this conclusion should be avoided, including (but not limited to) the following:

- The value that local residents place on green space is not (necessarily) entirely captured in the estimated house price premiums associated with proximity to green space (i.e. hedonic pricing is an indirect way to measure this value).
- The value of green space extends beyond just the value provided to local residents (e.g. it includes the broader population).
- There are positive externalities associated with access to green space, including physical and mental health benefits, which would not be captured in household willingness to pay. These broader socio-economic benefits to society could be higher in less affluent areas, for example if those areas would have comparatively higher levels of obesity / physical inactivity and mental health issues in the absence of green space.

Furthermore, whilst the absolute willingness-to-pay associated with increased proximity to green space increases with wealth (with average house prices being used as a proxy for wealth), the willingness-to-pay *relative* to wealth

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yields a more linear (and potentially negative) relationship.[29] This means that there appears (based on the study teams analysis of 32 LGA's using the Aither and IV Amenity tool) to be little difference in the *proportion* of wealth that households in Melbourne are willing to pay to live near to green space when purchasing a new home.

Additional uncertainties associated with the results include:

- These amenity values are based on 2016 house price data, which is the basis for the Amenity Tool calculations. While these figures have been uprated to 2021 dollars using the inflation rate for new dwelling purchase by owner-occupiers, this is still likely to undervalue house prices in 2021 in Melbourne which have increased by over 30 per cent on average over this period, more than four times the rate of inflation used over the same period.

- The results rely on the estimates of price elasticities from one hedonic pricing study in Melbourne, by Aither and IV which is subject to some limitations (such as not accounting for the size, quality or unique characteristics of the assessed parks).

- The approach to valuing all parks at the marginal value of an additional park is considered to be conservative. Further consideration should be given to the validity of this conclusion given the principle of diminishing marginal returns.

The results should therefore be interpreted as preliminary, order-of-magnitude estimates which provide a proof-of-concept for how amenity value can be estimated in urban Melbourne. It is recommended that these results are not used as the sole measure of benefits of green space, including in any prioritisation process for comparisons of the benefits of new parks in different locations. Consideration of how the approach could be refined in the future is set out in Section 5.4.

4.3. Education

The natural environment provides the opportunity to "learn about the characteristics of living systems" (EEA, 2018). Whilst learning about the natural environment can occur through everyday interactions with the outdoors, the focus of this assessment is on formal education, such as school trips and "citizen science" projects. The economic valuation literature suggests that there is substantial value associated with learning in the natural environment including the following benefits which may translate into both personal wellbeing and broader economic benefits over time (eftec, 2011; MJA, 2016):

– Direct educational value regarding the natural environment;
– Indirect educational value through learning skills that support academic competence such as mental focus / lower presenteeism and absenteeism, improved cognitive functioning, critical thinking, problem solving, self-direction in learning, analytical skills and a motivation for studying and lifelong learning;
– Life skills including social competence, resilience, teamwork, inclusivity, trust and leadership;
– Mental health benefits associated with lower levels of stress and tension, increased confidence and self-esteem and feeling of community connection;
– Increased environmental awareness and stewardship.

[29] This has been deduced based on an analysis of the proportional value of an additional park relative to the average house price within an LGA. So as average house prices increase, the proportional value of an additional park (relative to that house price) is estimated to remain (broadly) the same (there is potentially a negative effect but the study team determined that there are too few data points to conclude this with any certainty).

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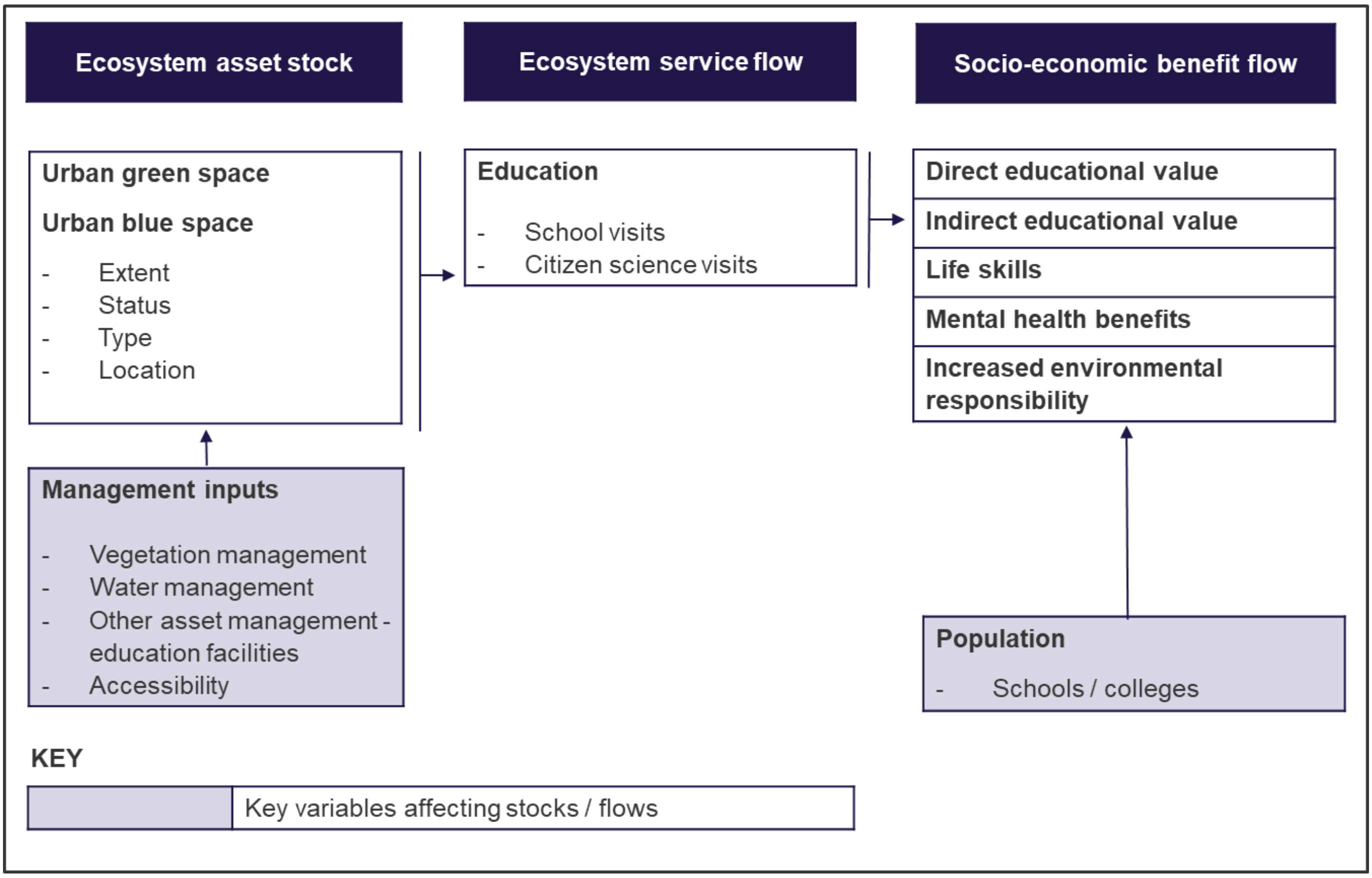
Figure 4.3.1. sets out the logic chain linking the ecological functioning of urban ecosystem assets to the socio-economic benefits.

Figure 4.3.1. Illustrative logic chain for education service of green-blue infrastructure



4.3.1. Physical provision of education

4.3.1.1. Methodology

The physical provision of education from urban ecosystem assets can be measured in environmental-economic accounts through the number of educational visits to Melbourne's urban ecosystem. Based on the literature review (see Annex 10, Section A10.2.), it was decided to that the physical provision of educational opportunities from ecosystem assets in the urban Melbourne region would be estimated using the Victorian Department for Education and Training (DET) Student Activity Locator database which is the most comprehensive information available on educational visitation in Victoria. All Victorian government schools must notify DET of approved school excursions to ensure accurate information is available for emergency services. Non-government schools are also able to access the Student Activity Locator to register excursions.

DET provided information on natural environment related educational visits to the suburbs (See Annex 12) that are within the urban Melbourne assessment boundary as recorded in the Student Activity Locator database. DET assigned visits to the natural environment within the urban Melbourne EEA region based on the activity classification that was used when registering the excursion. Natural environment activities include the following activity types: bushwalking, camp, caving, cycling, mountain bike riding, rock climbing, walking, water sports and sports.[30]

Prior to 2020, there was no information collected on the number of persons (students and teachers) visiting per school trip, only the number of school visits. In order to estimate the number of students visiting (necessary for the monetary valuation) the ecosystems within the urban Melbourne EEA region in 2019, the study team estimated the average number of student visitors per school visit for the year 2021 and applied this to the number of school visits. This assumes that the number of student visitors per educational trip was unaffected by the COVID-19 pandemic (i.e. when trips were able to go ahead, they number of attendees was the same as pre-COVID). This calculation resulted in an estimated 45 students per school visit (based on 2,791 visits to the natural environment within the Urban Melbourne EEA having 124,237 student visitors in 2021).

Total educational visits data was provided for the entire area of each suburb, whereas the area of some suburbs only partially falls within the urban boundary. In order to adjust for this and estimate the nature-based educational visits to the area of each suburb that fall within the urban accounting boundary, a proportion of total visits was calculated based on the proportion of total area of each suburb that falls within the urban Melbourne region. This implicitly assumes that nature-based educational visits are evenly distributed across the suburbs.

4.3.1.2. Results

The number of educational visits to the natural environment within the urban Melbourne EEA region in 2019 is estimated to be 6,545 based on the DET Student Activity Locator (2021). The most popular type of educational visit is excursions (2,495 visits), followed by camps (992 visits). These nature-related school visits within urban Melbourne are estimated to include 294,525 student visitors in 2019, as shown in Table 4.3.1.

Table 4.3.1. Number of school visits to suburbs within the urban Melbourne EEA by activity type for 2019

Activity type	School visits	School visitors	Year	Source
Bushwalking	345	15,525	2019	DET (2021)
Camp	992	44,640		
Camp-outdoor	1	45		
Caving	72	3,240		
Cycling	366	16,470		
Excursion	2,495	112,275		
Mountain bike riding	65	2,925		
Other	82	3,690		
Rock Climbing	168	7,560		
Sport	919	41,355		
Walking	948	42,660		
Water sport	92	4,140		
Total	**6,545**	**294,525**		

[30] Excursion, water sports and/or sport activities eligible for classification under natural environment activities were selected based on venue names with the following key words: bay, beach, caves, creek, dam, estuary, falls, farm, flora and fauna, forest, field trip, gardens, sanctuary, lake, lookout, park (excluding adventure, caravan, car, holiday and recreational parks, schools, shopping centres), outdoor ed. camp, outdoor education camp, paddock, parklands, picnic, pier, ranch, ranges, reserve, river, rock climbing (excluding indoor rock climbing), springs, steps, trail, tree, walking (excluding walking around the neighbourhood or local area), wetlands, You Yangs, zoo.

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The number of educational visits by suburb within urban Melbourne was also provided by DET. This shows that the most frequently visited suburbs within the urban Melbourne for nature-related educational trips in 2019 were Parkville (651 visits), Melbourne (349 visits) and Brunswick East (185 visits), as shown in Table 4.3.2 and Figure 4.3.2. which show the top 20 most visited suburbs for nature-based education and also has the estimated number of student visitors.

Table 4.3.2. Number of school visits/visitors to top-20 most visited suburbs within urban Melbourne in 2019

Suburb	School visits	School visitors	Year	Source
Parkville	651	29,295	2019	DET (2021)
Melbourne	349	15,705		
Brunswick East	185	8,325		
South Yarra	157	7,065		
Bundoora	150	6,732		
Frankston	149	6,708		
Wheelers Hill	119	5,355		
Keilor East	83	3,735		
Doveton	82	3,712		
Ferntree Gully	82	3,710		
Cheltenham	79	3,536		
Abbotsford	66	2,970		
Cranbourne East	65	2,929		
Moorabbin	56	2,517		
South Wharf	44	1,980		
Greensborough	44	1,966		
Frankston South	43	1,913		
Mornington	41	1,841		
Altona	41	1,828		
North Melbourne	39	1,755		
Total	**2,524**	**113,577**		

Figure 4.3.2. Top-20 most visited suburbs within urban Melbourne in 2019

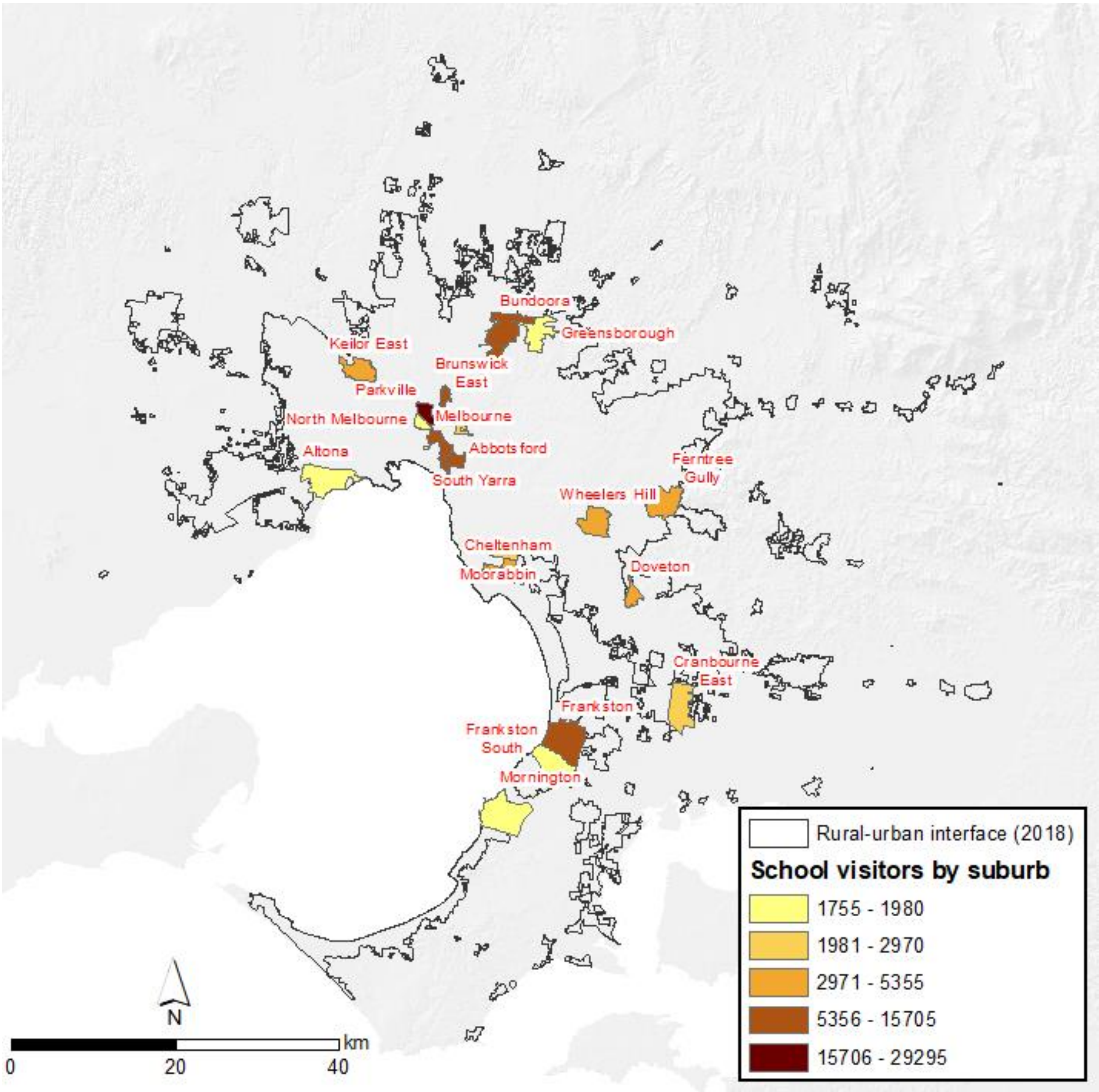

Table 4.3.3. summarises the uncertainty associated with these results and shows that there is a medium level of uncertainty associated with these estimates, which is partly because of uncertainty associated with the extent to which the database captures visits from non-government schools but also because of the assumptions regarding the proportion of visits that fall within the urban environmental-economic accounting boundary.

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Table 4.3.3. Uncertainty assessment - physical provision of education

	Uncertainty in…		
	Evidence	**Assumptions**	**Total**
Explanation	- The DET Student Activity Locator database is the most comprehensive information available on educational visitation in Victoria. All Victorian government schools must notify DET of approved school excursions to ensure accurate information is available for emergency services. Non-government schools are also able to access the Student Activity Locator to register excursions. It is unclear the extent to which the database captures visits from non-government schools.	- To estimate student visitors for 2019, the study team estimated the average number of visitors per school visit for the year 2021 and applied this to the number of school visits in 2019. This assumes that the number of visitors per educational trip was unaffected by the COVID-19 pandemic. - The proportion of total nature-based educational visits that falls within the urban accounting boundary was calculated based on the proportion of total area of each suburb that falls within the urban Melbourne region. This implicitly assumes that educational visits are evenly distributed across the suburbs.	Medium
Rating	2	2	4

4.3.2. Monetary value of education

4.3.2.1. Methodology

Based on the literature reviewed (see Annex 11, Section A11.3), economic valuation of educational activities in natural environments do not attempt to provide the "true economic value of educational benefits" because of a lack of quantitative evidence of the links between outdoor education and benefits (eftec, 2011). Instead, monetary valuation focuses on reporting the 'cost of investment' involved in these undertakings, using spending evidence as a proxy for value evidence (Mourato et al., 2011). Expenditures on educational activities are assumed to provide a lower bound estimate of the value of outdoor education on common economic assumption that if benefits were not perceived to be greater than costs then the activity would not be undertaken in the first place (UKNEA, 2011; eftec, 2011; Mourato, 2011). This approach was advocated in the DELWP and Parks Victoria (2015) study which states that "financial contributions…would be sufficient to indicate a lower-bound estimate of the benefits expected by education partners to access parks".

The monetary value of educational opportunities from ecosystem assets in the urban Melbourne EEA region is estimated using an expenditure approach based on the average cost for day trip and overnight activities respectively from the latest Australian Camping Association (2018) Prices and Occupancy Survey Report. The ACA (2018) report is a survey-based summary of member camps and adventure activity providers across Australia, with 74 per cent of

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respondents being from Victoria. For the 2016-17 financial year, the average charge for a day visitor was $9[31] (excluding GST) and for camping on site was $25[32] (excluding GST).

These estimated costs per educational trip were then applied to the total number of participants in educational trips (from DET Student Activity database) to get aggregate monetary value of educational trips to urban Melbourne ecosystem assets. These expenditures do not include transport costs, value of teachers in-vehicle travel time or the value of student time (as estimated in the UK by Mourato et al, 2011). These estimates are a very conservative representation of the value of these educational trips to society based on activity expenditures alone.

4.3.2.2. Results

The value of educational trips is estimated to be $3.4 million a year based on activity expenditures only. This consists of approximately $1.1 million per year from overnight visits and $2.3 million per year from day visits, as shown in Table 4.3.4.

Table 4.3.4. Estimated expenditure ($, 2021) on educational trips to urban Melbourne EEA region in 2019

		Estimate	Unit	Year	Source
Day visits	Day student visitors	249,840	Number visitors	2019	DET (2021)
	Expenditure per day visit	$9	$/visitor	2016-17[a]	ACA (2018)
	Total expenditure day visits	**$2,304,800**	$/year	-	-
Overnight visits	Overnight student visitors	44,685	Number visitors	2019	DET (2021)
	Expenditure overnight visits	$25	$/visitor	2016-17[a]	ACA (2018)
	Total expenditure overnight visits	**$1,133,600**	$/year	-	-

[a] These figures are representative of the year 2016-17 but are uprated for inflation to be in present value terms for 2021.

Table 4.3.5. summarises the uncertainty associated with these results and shows that there is high uncertainty associated with the approach taken to estimate a monetary value for educational visits to urban Melbourne. This is because the cost of visits is used which does not capture the total economic value of educational benefits.

[31] Updated to 2021 dollars from $8 using CPI adjustment from June 2017 to June 2021 for Domestic holiday travel and accommodation, Australia.
[32] Updated to 2021 dollars from $22 using CPI adjustment from June 2017 to June 2021 for Domestic holiday travel and accommodation, Australia.

Table 4.3.5. Uncertainty assessment - monetary value of education

	Uncertainty in…		
	Evidence	**Assumptions**	**Total**
Explanation	- The monetary valuation relies on the expenditure from the Australian Camping Association (2018) which is considered robust. - There is no estimate of total cost of educational visits including the broader expenditures associated with transport costs, value of teachers in-vehicle travel time or the value of student time. These estimates are therefore considered conservative and there is uncertainty regarding the total expenditure value. - Expenditure approaches do not capture the "true economic value of educational benefits" because of a lack of quantitative evidence of the links between outdoor education and benefits	- Expenditures on educational activities are assumed to provide a lower bound estimate of the value of outdoor education on common economic assumption that if benefits were not perceived to be greater than costs then the activity would not be undertaken in the first place. - The monetary values are presented in 2021 terms, uprating the original estimates for inflation.	High
Rating	3	3	9

4.3.3. Supply and use of education

It is not possible to attribute educational visits to specific ecosystems within the urban Melbourne EEA region. However, the beneficiaries / users of educational visits are households / society who benefit from the educational experience both directly (learning about the natural environment) and indirectly (i.e. learning skills that support academic competence) as well as life skills, mental health benefits and increased environmental awareness. These values are captured by industry through visit expenditures (based on the values estimated / the valuation methodology adopted for this EEA), as shown in Table 4.3.6.

Table 4.3.6. Supply and use table for education from the urban Melbourne EEA region in 2019

		Metric	Household	Government	Industry	Ecosystem
Education	Supply	Visitors / yr				113,577
	Use	Visitors / yr	113,577	-	-	-
Education	Supply	$ AUD (2021) / yr				$3.4m
	Use	$ AUD (2021) / yr	-	-	$3.4m	-

4.3.4. Discussion

The natural environment provides the opportunity to "learn about the characteristics of living systems" (EEA, 2018). Whilst learning about the natural environment can occur through everyday interactions with the outdoors, the focus of this assessment is on formal education, such as school trips and "citizen science" projects.

Information from DET's Student Activity Locator (2021) shows that there were a total of 294,525 student visitors across 6,545 educational trips to the natural environment within the urban Melbourne EEA region in 2019. The key hotspots for educational visits in 2019 were Parkville (29,295 visitors), Melbourne (15,705 visitors), Brunswick East (8,325 visitors), South Yarra (7,065 visitors), and Bundoora (6,732 visitors). These numbers alone signify the importance of urban ecosystems in Melbourne for providing a nature-related educational experience for Victorian's.

Expenditure on educational activities is assumed to provide a lower bound estimate of the value of outdoor education on common economic assumption that if benefits were not perceived to be greater than costs then the activity would not be undertaken in the first place (UKNEA, 2011; eftec, 2011; Mourato, 2011). The activity expenditure associated with educational trips to the urban Melbourne EEA region is estimated to be $3.4 million per year. This consists of approximately $1.1 million per year from overnight visits and $2.3 million per year from day visits. However, this approach to valuation does not capture the true economic value of educational benefits associated with these trips (an area for potential future research) and so this range is considered to be an underestimate of the economic value of these visits. See Section 5.4. for consideration of how the approach could be refined in the future.

4.4. Biomass - Food

Food production in Victoria predominately occurs at large-scale commercial agricultural farms in the rural areas outside of Greater Melbourne. However, food is produced from urban farms, community gardens, private gardens and rooftops. More detail on agricultural production within rural and peri-urban Melbourne is set out in Annex 10.3.

This urban agriculture provides a range of socio-economic benefits beyond the value of the food produced (i.e. reducing food bills), including (Victoria University, 2015):

– **Reduced food miles**: the consumption of locally produced food reduces the environmental impact of food in terms of processing, packaging and transport;
– **Increased biodiversity**: community and private gardens are less likely to be monocultures, and generally utilise production methods that are more environmentally friendly;
– **Social outcomes:** including education and stronger community networks;
– **Health outcomes**: locally produced food is likely to be fresher and healthier, and there are positive mental and physical wellbeing benefits associated with gardening; and
– **Economic outcomes**: personal income may be supplemented from selling produce.

Figure 4.4.1. sets out the logic chain linking the ecological functioning of urban ecosystem assets to the socio-economic benefits provided. It shows:

- Biomass provision for food from the urban Melbourne region will depend in part on the extent, status, type and location of ecosystems (habitats) and species as well as any management of these assets including additional nutrient provision (e.g. fertiliser), movement control on species stocks (e.g. livestock fencing) as well as pests and disease control.

- The harvesting of biomass to produce food requires the use of machinery, technology and labour.

- The contribution of the environment (i.e. biomass provision) to the socio-economic benefit provided (i.e. food provision) is valued using a resource rent approach by deducting the cost of man-made inputs (i.e. associated with asset management / harvesting) from the market price of food.

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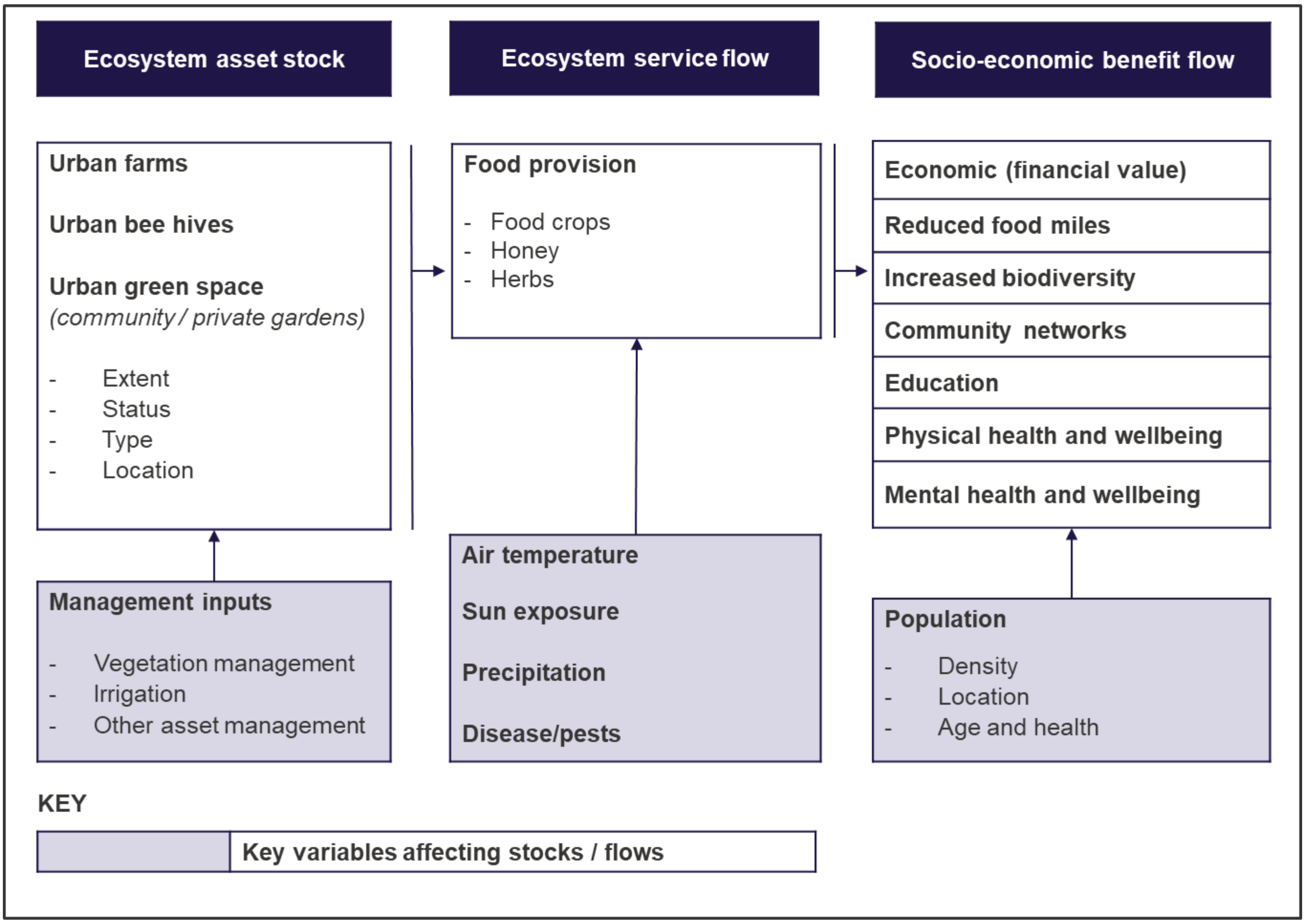
Figure 4.4.1. Illustrative logic chain for food production from urban ecosystem assets



Whilst there are a range of potential socio-economic benefits of food production that could be included in an environmental-economic account, the focus of this preliminary assessment is on the value of food production (other benefits are areas for future research) in terms of commercial production from urban farms and household production from community gardens.

4.4.1. Physical provision of biomass - food

4.4.1.1. Methodology

The physical provision of food production from urban ecosystem assets can be measured in environmental-economic accounts through the weight (kilograms or tonnes) of crops or livestock produced per year by different types of assets (enclosed farmland and gardens).

Based on the literature review (see Annex 10.3.) the following approach was taken to estimating the physical provision of food from ecosystem assets in Melbourne:

- **Commercial production**: the production of biomass as crops and livestock from enclosed farmland within the urban Melbourne EEA region was measured using data from the ABS *Agricultural Commodities, Australia 2018-19* dataset. This dataset contains information on the volume (tonnes) of agricultural production and numbers of livestock per year for farmland within Victoria at SA4 level. The total area of farmland in the urban Melbourne region (determined through the extent mapping) was compared to the total area of farmland within the SA4 regions which fall within the urban area (see Table 4.4.1. and Figure 4.4.2.). The percent proportion of farmland within the urban Melbourne region was then applied to the total volumes of agricultural produce and the numbers of livestock at SA4 level from the ABS data.

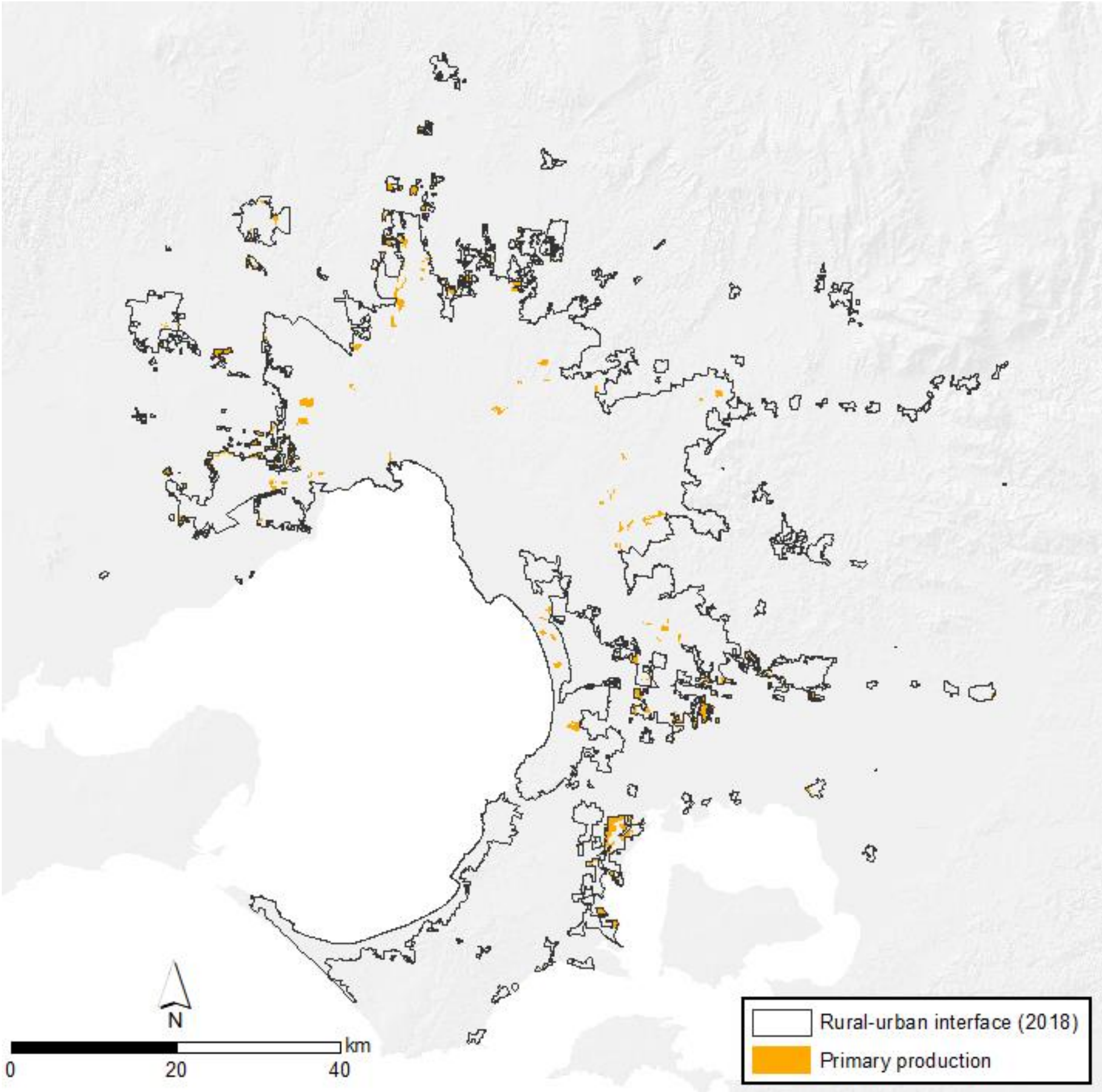
It is acknowledged this is a crude approach to determining the proportion of agricultural production occurring in the urban Melbourne region. The study team considered estimating the average per hectare volumes for different types of agricultural produce at SA4 level and applying these to the area of agricultural land within the urban Melbourne region, however the VLUIS land use classifications could not be reconciled with ABS produce classifications to produce justifiable results.

Table 4.4.1. Estimated area of farmland in urban Melbourne EEA region (VLUIS, 2017)

SA4 region	Total farmland within SA4 (ha.)	Farmland within urban Melbourne EEA region (ha.)	Proportion of SA4 farmland within urban Melbourne EEA region[33]
Melbourne - Inner	2	2	100.0%
Melbourne – Inner-East	0.2	0.2	100.0%
Melbourne – Inner-South	183	111	60.9%
Melbourne – North-East	48,317	962	2.0%
Melbourne – North-West	84,583	1,079	1.3%
Melbourne – Outer-East	39,953	272	0.7%
Melbourne – South-East	90,725	2,041	2.2%
Melbourne – West	61,750	1,560	2.5%
Mornington Peninsula	30,640	661	2.2%

[33] The ABS data estimates slightly different areas of total agricultural land within the SA4 regions compared with the extent mapping. If the total farmland area within the urban Melbourne EEA region was compared with the ABS agricultural area, the proportions would be slightly different, however, this difference is not considered material, and so the extent mapping areas were chosen for consistency.

Figure 4.4.2. Primary production land use within urban EEA region (VLUIS, 2017)

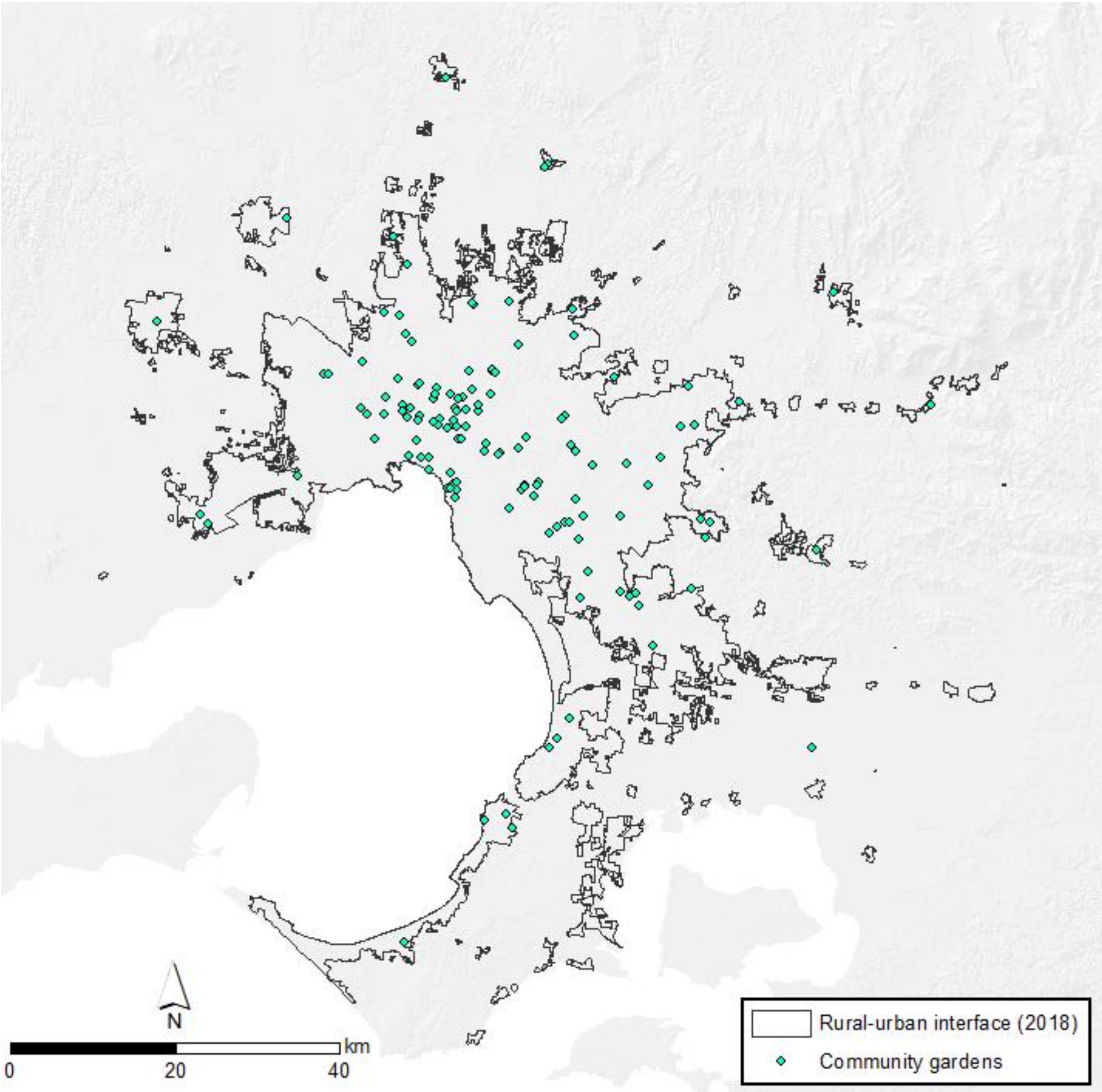


- **Community production**: Information from Zainuddin & Mercer (2014) study of daily yields from 15 households (plots) in Melbourne was used to estimate average annual food production yields in Melbourne of 0.49 to 3.68 kg per m^2 per year.[34] This was done by calculating average yield per square metre per day and then extrapolating this across the year. The average of this range is 1.92 kg/m^2/yr and this is used as the estimate of total annual local food production for this urban Melbourne EEA.[35] The estimates of average yield per square metre was then applied to an estimated community garden plot area across Melbourne of 24,840m^2 which was calculated based on:

[34] Outliers of 0.094 kg/m^2, 7.60 kg/m^2 and 10.91 kg/m^2 have been removed from this range.
[35] This value is consistent with the value applied in the UK Urban Natural Capital Accounts developed in 2017, which applied a yield of 1.95 kg/m^2.

o Community garden numbers using Australian City Farms & Community Network (ACFCN) (2018) data which lists 138 community gardens within the urban Melbourne region (see Figure 4.4.3.).[36] The ACFCN database relies on garden participants entering the details of the community garden they are affiliated with on a voluntary basis and is therefore likely to underestimate the total number of community gardens in Melbourne; and

Figure 4.4.3 Community gardens within urban EEA region (ACFCN, 2018)



o Average plot sizes (vegetated area) which were estimated using Google Maps for a sample of community gardens in Melbourne to be 180 m^2 per garden. The median of the plot size was used as an estimate to eliminate

[36] This includes a range of garden sizes from "pocket" gardens (~20m^2) to very large (~5,700m^2) gardens.

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gardens that are unusually large or small. The ACFCN data did contain information on garden size for select gardens, however this was not used given that it did not discern between actual garden bed and other areas of the garden such as paths and sheds.

Zainuddin & Mercer (2014) estimates of the percentage of total yield by produce types grown in domestic gardens was also used to estimate the amount (kg) of specific crops that are grown in urban Melbourne's community gardens, which is necessary for monetary valuation.

4.4.1.2. Results

- **Commercial Production**: Table 4.4.2. shows that commercial food production in urban Melbourne is estimated to produce:

  - 48,334 tonnes of crops, including 2,115 tonnes of hay and silage and 46,218 tonnes of broadacre crops.
  - 156,821 livestock, including 150,880 chickens, 1,261 sheep and lambs, 2,241 meat cattle and calves.
  - 8,954,004 eggs and 2,300 dairy cattle

Table 4.4.2. Estimated agricultural production within the urban Melbourne EEA region in 2018-19 (ABS)

Agricultural produce type	Metric (per year)	Estimated production with urban Melbourne EEA region
Broadacre crops	Tonnes	382
Fruit and nuts	Tonnes	536
Grapes – Wine production	Tonnes	355
Vegetables	Tonnes	44,946
Non-food crop produce		
- Hay and silage	Tonnes	2,115
Total crops	Tonnes	**48,334**
Livestock slaughtered		
- Sheep and lambs	Number	1,261
- Cattle and calves	Number	2,241
- Poultry	Number	150,880
- Other	Number	138
Total livestock	Number	**154,520**
Livestock products		
- Dairy cattle (milk)	Number	2,300
- Eggs	Number	8,954,004

- **Community production**: There is an estimated 47,693 kg of produce grown per year in urban Melbourne's community gardens, with the main types of produce grown by weight including fruit (7,154kg/year) and leafy greens (5,723kg/yr), as detailed in Table 4.4.3.

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Table 4.4.3. Fruit and vegetable production in Melbourne's community gardens (2018)

Produce type	Proportion of community garden production (% by type of produce)	Estimated production (kg/yr)
Fruit	15%	7,154
Cucumber	2%	954
Citrus	10%	4,769
Carrot	3%	1,431
Cabbage/ Cauliflower	2%	954
Capsicum/chilli	1%	477
Broccoli	3%	1,431
Beetroot	1%	477
Berry	2%	954
Beans	10%	4,769
Zucchini	4%	1,908
Tomato	4%	1,908
Salad Green	3%	1,441
Potato	1%	477
Pea	2%	954
Leek	3%	1,431
Leafy Green	12%	5,723
Herb	2%	954
Other	20%	9,539
Total		**47,693**

Table 4.4.4. summarises the uncertainty associated with these results and shows that there is high uncertainty associated with the estimates because for commercial production it is assumed that the proportion of all the agricultural production that occurs within the SA4 areas is representative of that occurring within the urban Melbourne region. The community garden estimates also have a high level of uncertainty as the evidence on the number, size and productivity of these gardens is limited which means the estimates rely on reasonable assumptions that are justified using the data available.

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Table 4.4.4. Uncertainty assessment - physical provision of biomass - food

	Uncertainty in…		
	Evidence	**Assumptions**	**Total**
Explanation	- There is no evidence on the actual area of productive farmland or the agricultural output and value specifically for the urban Melbourne region that is used. - There is very limited data on community garden numbers and extent in urban Melbourne, with no specificity on productive land area within each garden. - Community garden yield was drawn from the Zainuddin & Mercer (2014) study which had a small sample size (of 15).	- It is assumed that the proportion of *all* the agricultural production that occurs within the SA4 areas is representative of that occurring within the urban Melbourne region, whereas in reality, the mix of agriculture occurring within the urban Melbourne region is likely different to that occurring across the whole SA4 region. - Assumptions about average plot size are estimated using a rough extent calculation from Google maps, for a sample of 34 community gardens in urban Melbourne. - It is assumed that the estimated average annual yields from Zainuddin & Mercer (2014) are representative of the yields in community gardens across urban Melbourne.	High
Rating	3	2	6

4.4.2. Monetary value of biomass - food

4.4.2.1. Methodology

Based on the literature review (see Annex 11, Section A11.4.), existing data and analyses can be drawn on to estimate the monetary value ($AUD) of biomass for food produced by ecosystems within the urban Melbourne region, as quantified under the physical flow account, as follows:

- **Commercial production:** the production of biomass as crops and livestock from enclosed farmland within the urban Melbourne EEA region was valued using data from the ABS *Value of Agricultural Commodities Produced, 2019-20* dataset. This has information on the gross value ($) of agricultural produce per year for farmland within Victoria at SA4 level from the ABS. As for the physical provision, information on total area of farmland within the urban Melbourne region was taken from the extent mapping and compared to total farmland within the urban Melbourne SA4 regions (see Table 4.4.1. above). The percent proportion of agricultural area within the urban Melbourne region was then applied to the gross value of agricultural produce at SA4 level from the ABS data. A deduction of other input costs (e.g. labour and machinery) from the market value is needed to estimate the resource rent attributable to ecosystems. In the absence of information on gross margins, a resource rent of 20 per cent of the market value is used as an indicative estimate.

Unofficial

- **Community production:** The equivalent market price of the different crops that were estimated by Zainuddin & Mercer (2014) as being grown in community gardens in urban Melbourne was identified (for organic produce) from market prices listed on the Queen Victoria Market (2021) to estimate the value of production (avoided cost to households) across the area of community gardens in urban Melbourne. The "other" category of produce (as classified in Zainuddin & Mercer (2014)) is valued using the average (mean) price for all other produce. A deduction of other input costs (e.g. labour and machinery) from the market value is applied to estimate the resource rent attributable to ecosystems. In the absence of information on gross margins, a resource rent of 20 per cent of the market value is used as an indicative estimate.

4.4.2.2. Results

- **Commercial production:** The annual economic value ($AUD) of the contribution of ecosystems to agricultural production within the urban Melbourne EEA region is estimated to be approximately $8.7 million per year (with an assumed resource rent of 20 per cent applied), see Table 4.4.5. for more details including a breakdown of estimated value produced by different agricultural outputs.

Table 4.4.5. Estimated annual economic value ($, 2021) of agricultural production in Urban Melbourne EEA region in 2019-20

Agricultural produce type	Urban Melbourne production value ($/yr)	Resource rent ($/yr)
Broadacre crops	$174,402	$34,880
Fruit and nuts	$1,718,084	$343,617
Grapes – Wine production	$240,220	$48,044
Vegetables	$9,431,485	$1,886,297
Non-food crop produce		
Hay and silage	$402,340	$80,468
Nurseries, cut flowers, cultivated turf	$7,527,016	$1,505,403
Total crops	**$19,493,547**	**$3,898,709**
Livestock slaughtered		
Sheep and lambs	$125,600	$25,120
Cattle and calves	$12,513,149	$2,502,630
Pigs	$240	$48
Poultry	$5,597,990	$1,119,598
Other	$96,636	$19,327
Total livestock	**$18,333,615**	**$3,666,723**
Livestock products		
Milk	$3,748,396	$749,679
Eggs	$1,863,116	$372,623
Wool	$33,190	$6,638
Total livestock products	**$5,644,702**	**$1,128,940**
Total all produce	**$43,471,862**	**$8,694,372**

- **Community production**: The annual economic value ($AUD) of community food production within the urban Melbourne EEA region is estimated to be approximately $64,000 per year (with an assumed resource rent of 20 per cent applied), see Table 4.4.6.

Table 4.4.6. Estimated annual economic value ($, 2021) of agricultural production in urban Melbourne EEA region

Produce type	Estimated production (kg/yr)	Market cost per kg ($)	Value of production (Avoided costs) ($/yr)	Resource rent ($/yr)
Fruit	7,154	$4.0	$28,616	$5,723
Cucumber	954	$8.6	$8,175	$1,635
Citrus	4,769	$2.5	$11,923	$2,385
Carrot	1,431	$2.5	$3,577	$715
Cabbage/ Cauliflower	954	$46.0	$5,723	$1,145
Capsicum/chilli	477	$7.0	$3,339	$668
Broccoli	1,431	$5.0	$7,154	$1,431
Beetroot	477	$5.0	$2,385	$477
Berry	954	$11.0	$10,492	$2,098
Beans	4,769	$5.0	$23,846	$4,769
Zucchini	1,908	$6.0	$11,446	$2,289
Tomato	1,908	$8.5	$16,216	$3,243
Salad Green	1,441	$7.0	$10,015	$2,003
Potato	477	$3.0	$1,431	$286
Pea	954	$13.0	$12,400	$2,480
Leek	1431	$8.0	$11,446	$2,289
Leafy Green	5,723	$10.0	$57,231	$11,446
Herb	954	$100.0	$95,385	$19,077
Other	9,539	$11.8	$112,380	$22,476
Total	**47,693**		**$320,801**	**$64,160**

Table 4.4.7. summarises the uncertainty associated with these results and shows that whilst the market value of agricultural produce is well documented, the monetary estimates rely on the underlying estimates of physical provision and therefore reflect the high uncertainty associated with this. The estimate of resource rent is also highly uncertain.

Table 4.4.7. Uncertainty assessment - monetary value of biomass - food

	Uncertainty in…		
	Evidence	**Assumptions**	**Total**
Explanation	- There is no evidence on the actual agricultural value of output specifically for the urban Melbourne region within this study. - The monetary values rely on the underlying estimates of physical provision which are highly uncertain due to limited data on community garden numbers, extent and productivity. - The evidence on the market value of food that is used to value community garden production is well documented and expected to be robust.	- As per physical provision, it is assumed that a proportion of *all* the agricultural production value that occurs within the SA4 areas is representative of that occurring within the urban Melbourne region, whereas in reality, the mix of agriculture occurring within the urban Melbourne region is likely different to that occurring across the whole SA4 region. - An estimated 20 per cent of the market value is taken as the estimate of resource rent. - The monetary values are presented in 2021 terms, uprating the original estimates for inflation.	High
Rating	3	3	9

4.4.3. Supply and use of biomass - food

The production of crop and livestock biomass that is supported by farmland ecosystems and community gardens delivers direct benefits to the agricultural industry and households respectively, who are therefore deemed to be the users of this ecosystem service, as shown in Table 4.4.8. Indirect benefits of commercial agricultural production occur to the wholesale industry, downstream businesses and consumers.

The $8.7 million value that is attributable to urban ecosystems within Melbourne in Table 4.4.8. includes some produce that are not quantified in the physical account and so are not included in the physical provision section of this supply and use table. Most notably, $1.5 million of value from “Nurseries, cut flowers, cultivated turf” has no corresponding physical estimate.

Table 4.4.8. Supply and use table for biomass for food from the urban Melbourne EEA region

		Metric	Household	Government	Industry	Ecosystem
Biomass - food	Supply	Crop tonnes / yr				48,000
		Livestock No. / yr				155,000
		No. of Dairy Cattle / yr				750,000
		Eggs / yr				27,600
	Use	Crop tonnes / yr			48,000	
		Livestock No. / yr			155,000	
		No. of Dairy Cattle / yr			750,000	
		Eggs / yr			27,600	
Biomass - food	Supply	$ AUD (2021) / yr				$8.8m
	Use	$ AUD (2021) / yr	$0.06m		$8.7m	

Unofficial

4.4.4. Discussion

Commercial production of crop and livestock biomass in the urban Melbourne region is supported by ecosystems which provide a range of ecological functions that enable species to live and grow. Analysis for this urban Melbourne EEA suggests there is a substantial agricultural production within the urban Melbourne EEA region including 48,000 tonnes of arable output (crops and hay) and 155,000 livestock valued at around $8.7 million a year based on resource rent provided by urban ecosystems (i.e. isolating the contribution of the ecosystem from other inputs such as labour and machinery). Of this $8.7 million, $7.1 million is the contribution from the production of food, while $1.6 million is from other production such as hay, flowers or turf. The value to households of community garden production in urban Melbourne is estimated to be worth around $60,000 per year based on avoided costs alone (i.e. not accounting for the range of other benefits of community garden production).

Comparison with existing studies into food production with urban Melbourne suggest that this figure of $8.7 million is consistent with other estimates. For example, Deloitte (2014) estimated agricultural production from Inner Melbourne to be approximately $40 million in 2010-11, adjusting for inflation this gives a value of approximately $50 million in 2021. This Deloitte (2014) estimate does not isolate the ecosystem contribution to value, which has been estimated using a 20 per cent resource rent within this urban Melbourne EEA. Applying this estimate of resource rent to the Deloitte (2014) figure gives an estimated value of agricultural production in Melbourne of $10 million in 2021, which is broadly consistent with the figures estimated by the study team for this urban Melbourne EEA.

These values are estimated using justifiable assumptions based on limited evidence and should be interpreted as useful order-of-magnitude estimates that provide a proof-of-concept for how the ecosystem service of biomass for food can be assessed in the urban Melbourne context. Consideration of how the approach could be refined in the future is outlined in Section 5.4.

4.5. Global climate regulation

Vegetation within urban Melbourne sequesters carbon dioxide from the atmosphere and stores it as organic carbon in plant biomass (trunks, branches, foliage and roots) and soil. The sequestration and storage of carbon over long time periods in vegetation and soil plays a vital role in regulating the earth’s climate and mitigating climate change. Carbon is also lost from vegetation and soil carbon stocks due to (i) emissions to the atmosphere due to degradation and/or disturbances such as fire (ii) removals from ecosystems when biomass is harvested or collected and is stored in wood products until burned or degraded.

There are several ways climate regulation services can be conceptualised in an environmental-economic accounting context, specifically (i) Gross carbon sequestration approach (ii) Net carbon sequestration approach (iii) Carbon retention approach, see detailed explanation of each in Annex 10, Section A10.4. For the purpose of developing this urban Melbourne EEA, gross sequestration and carbon retention approaches were developed based on data and analysis available for the region within the timing and resources available for this project.

Figure 4.5.1. sets out the logic chain linking the ecological functioning of ecosystem assets to the socio-economic benefits provided (note not all of these benefits are mutually exclusive).

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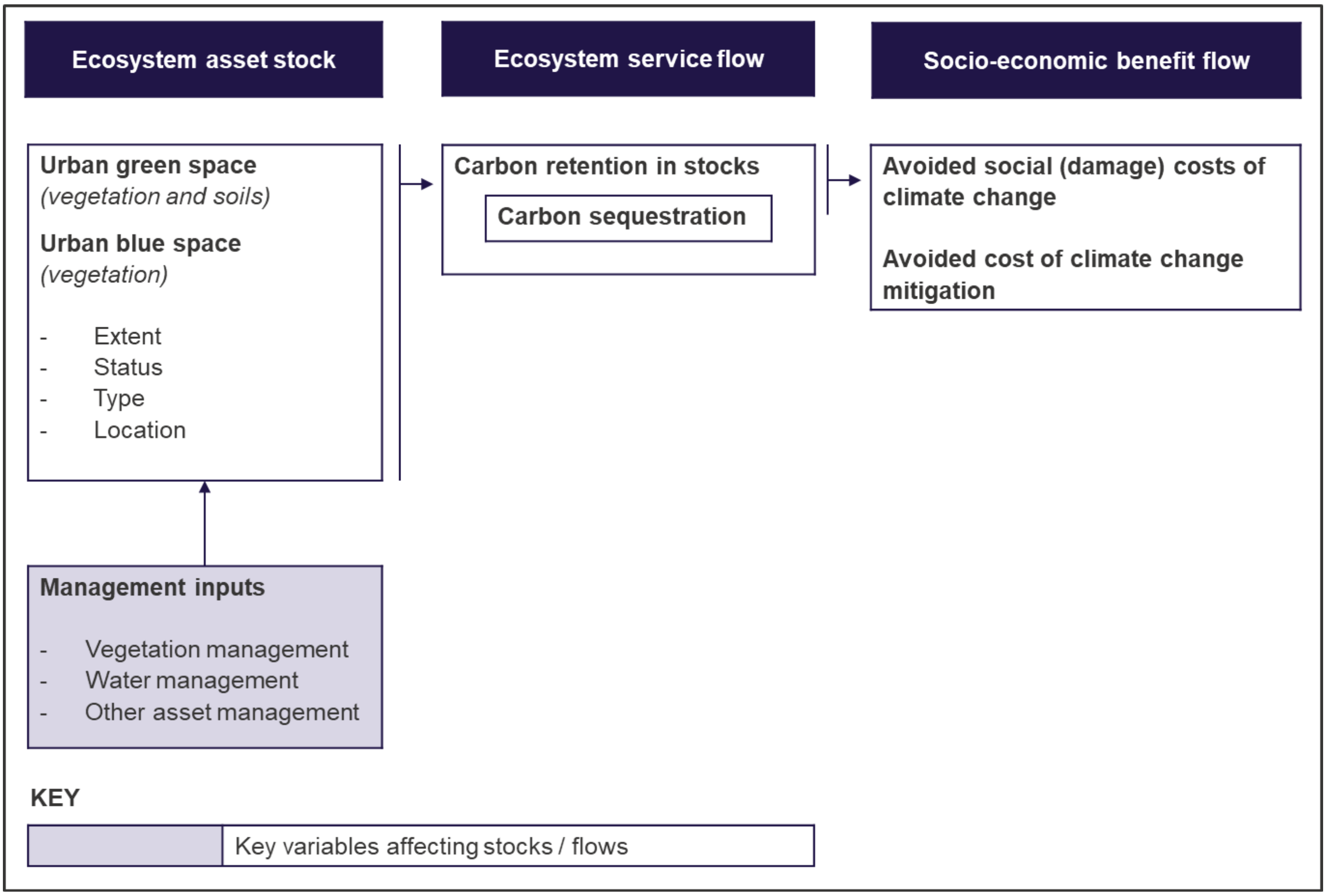
Figure 4.5.1. Illustrative logic chain for global climate regulating service



4.5.1. Physical provision of global climate regulation

4.5.1.1. Methodology

The physical provision of the global climate regulating service of ecosystem assets can be measured in environmental-economic accounts through the tonnes of carbon (CO_2e) retained and / or sequestered annually.

Based on the literature review (see Annex 10, Section A10.4.), it is understood that there is no single methodology that estimates carbon retention or carbon sequestration (net and / or gross) for all ecosystems within urban Melbourne. Several approaches are therefore required to build an estimate of global climate regulation for the region that is as comprehensive as possible given the data available. The following approaches to estimating the global climate regulating service of ecosystem assets within urban Melbourne are adopted:

i) Carbon retention

The approach taken to estimating the physical provision of carbon retention in the urban Melbourne region is to utilise DISER FullCAM estimates of carbon retention. This approach utilises, and is therefore consistent with, the Commonwealth Department of Industry, Science, Energy and Resources (DISER) Full Carbon Accounting Model (FullCAM) which is used to compile Australia's national greenhouse gas inventory system for the land sector and generate abatement estimates for vegetation under the Emissions Reduction Fund (ERF).

Unofficial

FullCAM utilises Landsat satellite imagery with 25 metre resolution pixels for urban canopy identification, with a forest or non-forest state determined by the pixel colour being interpreted as above or below a 20 per cent canopy threshold. For example, the modelling would produce a non-forest response on top of the Melbourne Museum, but a forest response in parts of the Carlton Gardens. While FullCAM does account for carbon stocks captured in soils, this is similarly determined by the pixel identification, with no soil carbon stock assumed for areas that fall below the canopy threshold.

Carbon retention can be quantified as the total stock of carbon stored in an ecosystem over an accounting period. (Consequently, the change in carbon retention ecosystem service flow from one year to the next is equal to net carbon sequestration). For the purposes of environmental-economic accounting, this asset stock (i.e. total stock of carbon) needs to be converted into an annual flow.

The approach to estimating an annual flow from an asset value is to use conventional accounting techniques.[37] For example, by valuing the carbon stock and using an annuity approach to create an annual flow value. Supply of carbon retention services in a year (year t) can be valued using an annuity approach as follows:

- Carbon stock in year t is converted to CO_2e and valued by using a suitable carbon value for year t.
- The carbon stock value is converted into a series of uniform annual values using a discount rate of 4 per cent[38] over a period of 100 years. The annual payment represents the value of ecosystem service flow in year t.
- This can be repeated to value ecosystem service flow in year t+1 and beyond, based on carbon stock in year t+1 and a suitable carbon value for year t+1.

One hundred years is selected as the asset (carbon stock) life as this aligns with the maximum asset life suggested for valuation of ecosystem assets.[39] That is, an ecosystem asset is expected to generate ecosystem services over 100 years and its value can be estimated as the net present value of expected future returns (ecosystem service flows). The hypothetical assumption is that carbon is stored for 100 years and then disappears overnight: there is no gradual depreciation of the carbon stock. Another option would be to assume an infinite asset life – that carbon is stored in perpetuity. Note that a shorter time period will result in a higher annual payment and consequently a higher ecosystem service flow value. Therefore, using a longer time period represents a more conservative approach to valuing supply of carbon retention services.

ii) Carbon sequestration

It was not possible to obtain estimates of carbon sequestration for land ecosystems from DISER using FullCAM (used to compile Australia's national greenhouse gas inventory system for the land sector) within the time constraints of this project. The study team identified carbon sequestration estimates for inland wetlands, parks and trees / forests from the literature. The estimates for carbon sequestration in the urban Melbourne EEA region are therefore partial as they do not cover all urban ecosystem assets. The approaches taken to estimating the physical provision of carbon sequestration in the urban Melbourne region are summarised below:

- **Inland wetlands**: use estimates of carbon stocks from Carnell et al (2016): This approach utilises estimates of tonnes of carbon sequestered for inland wetlands within urban Melbourne region by drawing on average

[37] Authors unknown 2020, Discussion paper 3.2: Treatments for selected ecosystem services and related flows for the revised SEEA EEA. February 2020, p. 19.

[38] Consistent with Victorian Department of Treasury and Finance guidance on discount rates. Department of Treasury and Finance 2013, *Economic evaluation: Technical guidance*, State of Victoria, Melbourne, pp 24-27.

[39] United Nations Statistics Division 2020, 'Chapter draft prepared for global consultation – Chapter 10: Accounting for ecosystem assets in monetary terms', System of Environmental-Economic Accounting 2012 – Experimental Ecosystem accounting Revision, May, p. 9-10.

Unofficial

estimates for inland wetlands in Victoria of 6.93 tonnes of carbon dioxide equivalent per hectare per year from Carnell et al (2016) and applying this figure to the area of inland wetlands from the extent account.

– **Trees and forests:** use estimates of carbon sequestration from DELWP and Parks Victoria (2015) and England et al. (2006): This approach involved the identification of the number (or area in hectares) of trees within the urban area of the assessment boundary using data from the extent account. Estimates of CO_2e sequestration of 3.5 tonnes CO_2e per ha per year for urban forests (broad ecosystem asset) or 0.007 tonnes CO2e per tree per year (narrow ecosystem asset) from the literature were then applied to the number of trees to provide an indicative figure for the gross amount of carbon sequestered annually by Melbourne's green infrastructure. The 3.5 tonnes of carbon dioxide equivalent per hectare per year is the average of the values of between 2.5 and 5 tonnes CO_2e / ha / year which are consistent with the wider literature on the carbon sequestration value of afforested areas, see unit values in Table 4.5.1.

Table 4.5.1. Unit values for CO_2e sequestration from the literature

Asset	Incidence	Unit	Source
Trees / Forests	0.011	tonnes CO_2e / tree / year	DELWP and Parks Victoria (2015)
	5	tonnes CO_2e / ha / year	
	0.0055	tonnes CO_2e / tree / year	England et al. (2006)
	2.5	tonnes CO_2e / ha / year	

Accumulation of carbon in biomass after afforestation varies greatly by tree species and site and ranges globally between 1 and 35 t CO_2/ha/yr (Richards and Stokes, 2004 in IPCC, 2007). Brown (2009) states that newly planted tree seedlings in temperate regions (which Melbourne is) remove an average of 6.5 tonnes CO_2e/ha/year (equivalent to 0.013 tonnes of CO2 per tree per year, assuming 500 trees per hectare). The UK Urban Natural Capital Account adopted an average rate of sequestration of 5 tonnes CO_2e/ha/year across the UK (eftec et al, 2017).

– **Parks**: use estimates of carbon sequestration from DELWP and Parks Victoria (2015): This approach involved the identification of the area (in hectares) of parks within the urban area of the assessment boundary using data from the extent account. Estimates of CO_2e sequestration per hectare from the literature were then applied to the area of park to provide an indicative figure for the gross amount of carbon sequestered annually by Melbourne's parks. The unit values used are set out in Table 4.5.2.

Table 4.5.2. Proposed physical unit values for CO_2e sequestration

Asset	Incidence	Unit	Source
Parks	2	tonnes CO_2e / ha / year	DELWP and Parks Victoria (2015)

4.5.1.2. Results

i) Carbon retention

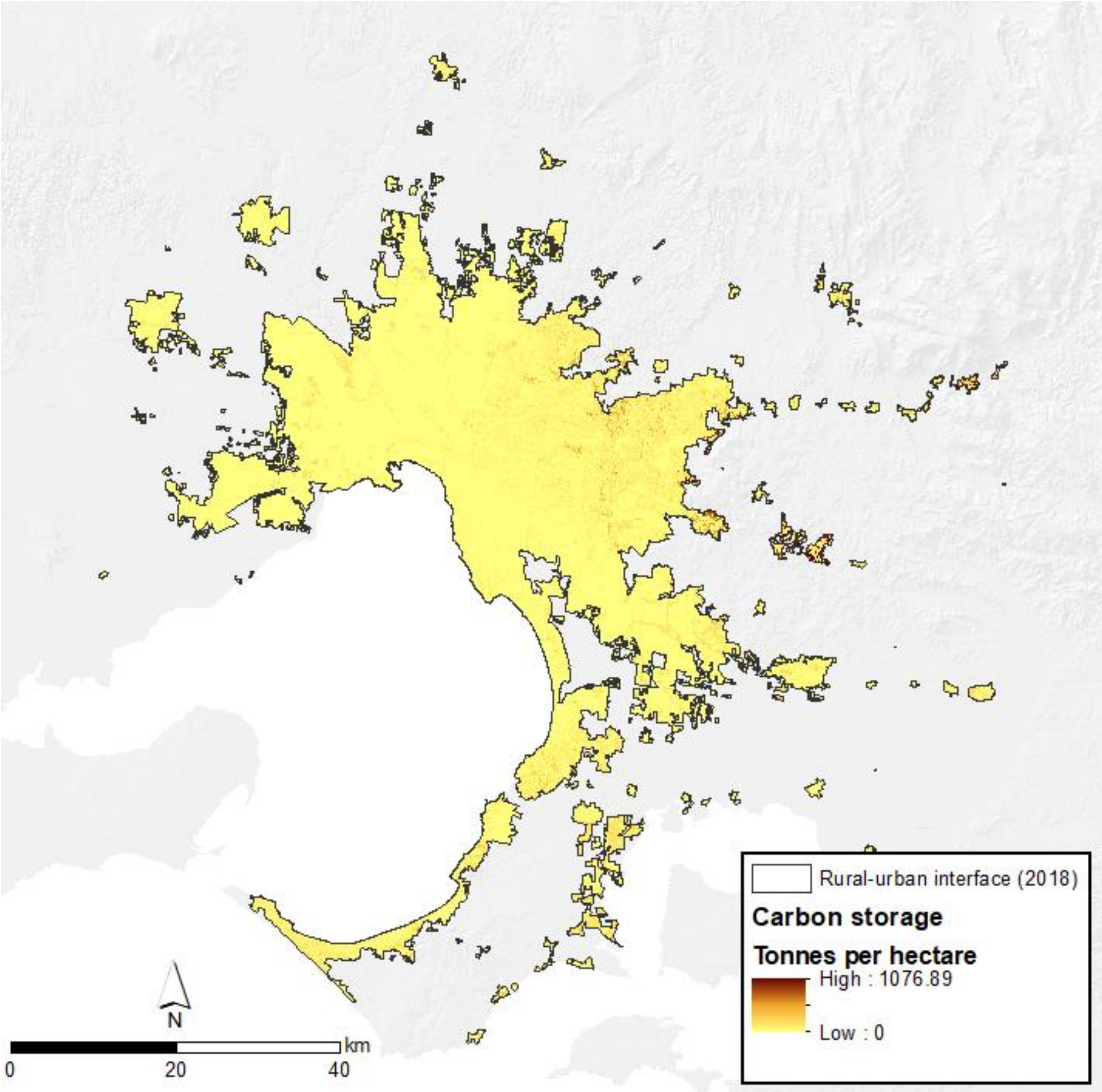
Analysis of the carbon mapping across ecosystem assets in the urban Melbourne EEA region estimates a total stock of 20.4 million tonnes of carbon dioxide equivalent (tCO2e), which is detailed by broad habitat in Table 4.5.3. and shown in Figure 4.5.2.

Unofficial

Table 4.5.3. Estimated carbon stock (tCO2e) from urban ecosystems within Melbourne in 2019 (DISER, 2021)

Urban asset type	Estimated total carbon stock (Tonnes)	Estimated total CO_2e stock (Tonnes)	Year	Source
Shrubland	34,087	124,894	2019	DISER (2021)
Grassland	417,320	1,529,059		
Forest / woodland	1,157,763	4,242,042		
Coastal margins	3,367	12,336		
Farmland	194,729	713,488		
Freshwater and wetland	116,284	426,063		
Urban – Built up areas	2,603,831	9,540,438		
Urban – Highly managed assets	1,028,275	3,767,600		
Total	**5,555,655**	**20,355,921**		

Figure 4.5.2. Spatial distribution of carbon stocks across urban Melbourne



ii) Carbon sequestration

Analysis of the inland wetland, forest and parkland of the urban Melbourne EEA region estimates that approximately 115,000 tonnes of carbon dioxide equivalent (tCO2e) is sequestered per year by these ecosystems across close to 40,000 ha (which is about half of the total extent of urban ecosystems of approximately 72,000 ha) in 2019, see Table 4.5.4. This provides a partial estimate of the role of the urban Melbourne EEA ecosystems in regulating the global climate based on a sub-set of ecosystems.

Unofficial

Table 4.5.4. Partial estimate of carbon sequestration from a subset of urban ecosystem assets in Melbourne in 2019

Urban ecosystem asset type	Estimated area in urban Melbourne EEA (ha)	Estimated marginal carbon sequestration (tCO2e / ha)	Estimated total annual carbon sequestration (tCO2e)	Year	Source
Inland wetland	194	6.93	**1,344**	2019	DELWP (2020); Carnell et al (2016), DELWP and Parks Victoria (2015), England et al. (2006)
Forest	13,870	3.5	**48,545**		
Parkland	31,892	2	**63,784**		
Total	37,931		**113,673**		

Based on available information on the number of street / city trees located in built up areas in the assessment boundary[40] (from Vicmap Vegetation Tree Urban dataset, DELWP (2021))[41], the carbon sequestration from street / city trees in the urban Melbourne EEA area is estimated at 36,400 tCO2e from over 5.2 million trees, see Table 4.5.5. This provides a partial estimate of the role of urban Melbourne trees in regulating the global climate through sequestering carbon.

Table 4.5.5. Partial estimate of carbon sequestration from street / city trees in Melbourne in 2019

Urban ecosystem asset type	Estimated number in urban Melbourne EEA (no.)	Estimated marginal carbon sequestration (tCO2e / tree)	Estimated total annual carbon sequestration (tCO2e)	Year	Source
Street / city trees	5,201,645	0.007	**36,412**	2019	DELWP (2021), DELWP and Parks Victoria (2015), England et al. (2006)

Table 4.5.6. summarises the uncertainty associated with these results and shows that the estimates of global climate regulation are considered to be of high uncertainty because of the accuracy of the model which the Vicmap Vegetation Tree Urban database is based on, as well as the low resolution of the information that is used to estimate carbon retention. The sequestration the estimates are based on a range of sources (i.e. there is a fairly broad evidence base) for these ecosystems and it is reasonable to assume that the average rates estimates from the literature are representative of the urban Melbourne EEA region.

[40] To avoid double counting, only city / street trees located within built up areas have been included. Trees have also been excluded based on the spatial distribution of parks (from the VPA Open Space dataset).

[41] This urban tree dataset did not completely cover the built-up areas within the assessment area (mostly in the far eastern extent), so an adjustment was made using the average density for the covered region, which was then applied to the built up areas of the uncovered region of the assessment area.

Table 4.5.6. Uncertainty assessment - physical provision of global climate regulation

	Uncertainty in…		
	Evidence	**Assumptions**	**Total**
Explanation	- It was not possible to obtain estimates of carbon sequestration across the entire urban Melbourne EEA region (DISER has the capability to produce this information). Estimates of carbon sequestration do exist for Victoria for a sub-set of habitats from a range of Victoria specific sources. - Estimates of carbon retention are from DISER using Full Carbon Accounting Model (FullCAM) which is used to compile Australia's national greenhouse gas inventory system for the land sector. These are relatively low resolution estimates as the analysis is developed at national level. - The Vicmap Vegetation Tree Urban dataset was used to estimate the number of trees in the urban area, however the dataset does not cover the entire assessment area (approximately 1.7 per cent of the total area was not covered by the urban tree extent). - The Vicmap Vegetation Tree Urban dataset is based on a model with accuracy of 78%. The model does not identify every tree and has known issues identifying trees in a dense canopy where many trees overlap.	- The sequestration rate of the ecosystems assessed is assumed to be consistent with the average rates estimated for these ecosystems in Victoria from the literature. - Assumes that the regions of the assessment area not covered by the urban tree database extent are of similar tree density as the remainder of the assessment area.	High
Rating	3	2	6

4.5.2. Monetary value of global climate regulation

4.5.2.1. Methodology

Based on the literature review (see Annex 11, Section A11.5.), monetary values for global climate regulation are presented in carbon dioxide equivalent (CO_2e)[42] terms and can be measured in environmental-economic accounts through the:

– **Social cost of carbon:** the social cost of carbon is a shadow price of CO_2-e that reflects its global social marginal cost. The global social cost of 1 tonne of CO_2-e emitted today is the present value of additional economic damages now and in the future caused by associated climate change impacts. There is great uncertainty around the global social cost of CO_2-e with a wide range of estimated damage costs reported in the literature (BDA Group, 2015).

[42] Tonnes of carbon sequestered and storage (retention) can be converted to CO_2e by applying an equivalent factor of 3.664 i.e. 1 tonne of carbon is equal to 3.664 tonnes of CO2e (DoEE, 2017).

– **Market price / Replacement cost**: An alternative method to place an economic value on greenhouse gas emissions is the replacement cost approach, through estimating the marginal cost of greenhouse gas abatement or offset measures. Assuming that Australia will act to meet an agreed greenhouse gas reduction target, the impact of carbon sequestration by vegetation is to reduce other activities needed for Australia to comply with this target. The value of the carbon sequestration provided by vegetation can therefore be measured through the cost savings associated with a reduction in other activities / projects needed for Australia to comply with this target.

For the purpose of this initial urban Melbourne EEA, estimates will be produced using both possible approaches based on the marginal unit values from the literature (see Table 4.5.7.) in order to provide a range of economic values for decision makers with an accompanying explanation of what the values represent. Social cost of carbon will be estimated at the average of US Government (2016) and Hope (2006) of $127 per tonne CO_2e (2021 value) and for the market value the latest price under the World Bank Carbon Pricing Dashboard will be used of $42 tonne CO_2e (2021 value) on the basis that this represents a central estimate based on the range of possible exchange values (market prices/replacement costs) set out in Table 4.5.7.

Table 4.5.7. Monetary unit ($, 2021) values for global climate regulation

Type of value	Value	Unit	Year	Source
Social cost of carbon	$75[43]	$ / tonnes CO_2e	2016	US government (2016)
	$178[44]	$ / tonnes CO_2e	2006	Hope (2006)
Market prices / replacement cost	$42[45]	$ / tonnes CO_2e	2019	World Bank Carbon Pricing Dashboard
	$16[46]	$ / tonnes CO_2e	2019	Commonwealth's Emissions Reduction Fund
	$74[47]	$ / tonnes CO_2e	2019	IPCC Fifth Assessment Report

4.5.2.2. Results

4.5.2.2.1 Monetary value of global climate regulation

i) Carbon retention

Applying the unit (per tonne CO_2e) dollar values for social cost of carbon and market price/replacement cost to the total stock of carbon and annualising this over 100 years at 4 per cent discount rate, results in a range of monetary estimate for the carbon sequestered by the ecosystems within urban Melbourne in 2019 of $35 million a year (market price/replacement cost) to $106 million a year (social cost of carbon), as shown in Table 4.5.8.

[43] Updated to 2021 Australian dollars from US$42 (2020 value in 2007 dollars) using average AUD/USD exchange rate in 2006/07 of $0.79 (Reserve Bank of Australia, Historical Exchange Rates) and CPI adjustment from June 2007 to June 2021 for All groups CPI, Australia.
[44] Updated to 2021 Australian dollars from US$67 (2020 value – adjusted from 2001 value with growth of 2.4% p.a.) using average AUD/USD exchange rate in 1999/2000 of $0.63 (Reserve Bank of Australia, Historical Exchange Rates) and CPI adjustment from June 2000 to June 2021 for All groups CPI, Australia.
[45] Updated to 2021 Australian dollars from US$28 (2020 value – global average of implemented carbon taxes) using average AUD/USD exchange rate in 2019/20 of $0.67 (Reserve Bank of Australia, Historical Exchange Rates) and CPI adjustment from June 2020 to June 2021 for All groups CPI, Australia.
[46] Updated to 2021 dollars from $16 using CPI adjustment from September 2020 to June 2021 for All groups CPI, Australia.
[47] Updated to 2021 dollars from $71 using CPI adjustment from December 2018 to June 2021 for All groups CPI, Australia.

Table 4.5.8. Estimated monetary value ($, 2021) of carbon stock of ecosystems within urban Melbourne in 2019

Urban Habitat	Estimated total CO_2e stock (Tonnes)	Estimated monetary value ($m)		Annual estimated monetary value ($m/yr)		Year	Source
		Market price	Social cost of carbon	Market price	Social cost of carbon		
Shrubland	124,894	$5m	$16m	$0.2m	$1m	2019	World Bank Carbon Pricing Dashboard; US government (2016) and Hope (2006)
Grassland	1,529,059	$64m	$194m	$3m	$8m		
Forest / woodland	4,242,042	$179m	$539m	$7m	$22m		
Coastal margins	12,336	$1m	$2m	$0.02m	$0.1m		
Farmland	713,488	$30m	$91m	$1m	$4m		
Freshwater and wetland	426,063	$18m	$54m	$1m	$2m		
Urban – Built up areas	9,540,438	$402m	$1,213m	$16m	$50m		
Urban – Highly managed assets	3,767,600	$159m	$479m	$7m	$20m		
Total	**20,355,921**	**$859m**	**$2,589m**	**$35m**	**$106m**		

ii) Carbon sequestration

Applying the unit (per tonne CO_2e) dollar values for social cost of carbon and market price/replacement cost results in a range of monetary estimate for the carbon sequestered by the inland wetland, forest, parkland and street tree ecosystems within urban Melbourne EEA in 2019 of $6 million a year (market price/replacement cost) to $19 million a year (social cost of carbon), as shown in Table 4.5.9.

Table 4.5.9. Estimated monetary value ($, 2021) of carbon sequestration from sub-set of ecosystems within urban Melbourne in 2019

Urban ecosystem asset type	Estimated total annual carbon sequestration (tCO2e)	Estimated monetary value - market price ($)	Estimated monetary value - social cost of carbon ($)	Year	Source
Inland wetland	1,344	$0.1m	$0.2m	2019	World Bank Carbon Pricing; US government (2016) and Dashboard
Forest	48,545	$2m	$6m		
Parkland	63,784	$3m	$8m		
Street / city trees	36,412	$2m	$5m		
Total	**150,085**	**$6m**	**$19m**		

Table 4.5.10. summarises the uncertainty associated with these results and shows that there is significant uncertainty associated with the valuation of carbon in the absence of an explicit price for carbon in Australia. There are limitations to both social cost of carbon and market prices/replacement cost estimates.

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Table 4.5.10. Uncertainty assessment - monetary value of global climate regulation

	Uncertainty in…		
	Evidence	**Assumptions**	**Total**
Explanation	- There are a range of prices for carbon. Market pricing of carbon can be reflective of the institutional setup (including the underpinning regulatory framework) of the market, rather than the “true” value that would exist in a well-functioning market. Prices based on the carbon mitigation that is necessary to meet a defined target are based on market principles related to marginal abatement cost curves, but these can also be uncertain. - Estimating the social cost of carbon requires modelling future scenarios which is inherently uncertain.	- It is assumed that the global carbon values, both social cost of carbon and market price/replacement cost estimates are relevant in the urban Melbourne EEA context. In the absence of an explicit carbon price in Australia this is deemed to be appropriate.	High
Rating	3	3	9

4.5.3. Supply and use of global climate regulation

The users of the global climate regulating ecosystem service provided by urban Melbourne ecosystem assets is the global community who benefits from the reduced impact of climate change and the Victorian/Australian households, businesses and government who benefit from the reduced cost of meeting the countries climate change targets (relative to a “no natural capital” measurement baseline). The supply and use table is populated for carbon retention only as this is comprehensive covering all ecosystems (as opposed to carbon sequestration which only covers trees and parks), see Table 4.5.11.

Unofficial

Table 4.5.11. Supply and use table for global climate regulation (carbon retention) from the urban Melbourne EEA ecosystems in 2019

		Metric	Household	Government	Industry	Grassland	Shrubland	Forest / woodland	Farmland	Freshwater and wetland	Urban	Coastal margins
Global climate regulation	Supply	tCO_2e / yr				62,000	5,000	173,000	29,000	17,000	543,000	500
	Use	tCO_2e/ yr	831,000									
Global climate regulation	Supply	$ AUD (2021) / yr				$3m to $8m	$0.2m to $0.6m	$7m to $22m	$1m to $3m	$1m to $2m	$23m to $69m	$0.1
	Use	$ AUD (2021) / yr	$35m to $106m									

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4.5.4. Discussion

Vegetation within the urban Melbourne terrestrial ecosystem[48] sequesters carbon dioxide from the atmosphere and stores it as organic carbon in plant biomass (trunks, branches, foliage and roots) and soil. The global climate regulating service of ecosystem assets in the urban Melbourne EEA region is measured through the tonnes of carbon (CO2e) retained across the region and separately the tonnes of carbon (CO2e) sequestered annually. The analysis shows:

- **Carbon retention:** under the retention approach, the ecosystem service is conceptualised as the retention of carbon in an ecosystem (i.e. the avoided release of carbon). This is quantified by measuring the stock of carbon in an ecosystem over an accounting period, converted into an annual flow using an annuity approach. The results show an estimated 20.4 million tonnes of carbon dioxide equivalent is stored in the ecosystems of urban Melbourne, provides an annual value of $35 million per year to $106 million per year.

- **Carbon sequestration:** this approach measures the gross annual addition to carbon stocks within the urban Melbourne region.[49] That is, the removal of carbon from the atmosphere and storage in plant biomass as an ecological function. An estimated 150,000 tonnes of carbon (CO2e) is sequestered annually at a value of $6 million per year to $19 million per year by some of the ecosystems of the urban Melbourne EEA region, specifically inland wetland, forest, parkland and street trees.

The results from these two approaches are not additive but demonstrate the range of ways the global climate regulating ecosystem service can be assessed. The values are estimated using justifiable assumptions based on limited evidence and should be interpreted as useful order-of-magnitude estimates that provide a proof-of-concept for how the ecosystem service of global climate regulation can be assessed in the urban Melbourne context. Consideration of how the approach could be refined in the future is set out in Section 5.4.

4.6. Local climate regulation

The current total socio-economic costs of “extreme heat” in Melbourne (including heatwaves and single hot days over 30°C) are estimated to be significant, including productivity losses from heatwaves in Melbourne of $53 million per year and wider costs to the community from extreme temperatures in the City of Melbourne (CBD only) such as additional hospital visits and deaths of $79 million per year, see Annex 10, Section A10.5. The costs of extreme heat are borne by all economic units including the government, communities and businesses.

Urban ecosystem assets including urban parks, gardens, green roofs, street trees, rivers and lakes regulate temperature and humidity, including through ventilation and transpiration (EEA, 2018). The estimated costs of extreme heat to the economy and wider community, that is exacerbated by the urban heat island effect, would be higher without urban Melbourne’s ecosystem assets that are embedded into the urban fabric.

The current socio-economic costs of high temperatures are likely to increase in the future due to population growth, increased urbanisation (which will intensify the urban heat island effect) and climate change unless careful planning is undertaken to maintain and expand urban ecosystem assets in Melbourne. The “local climate regulating effect” of

[48] There are other green-blue infrastructure features / urban ecosystem assets that capture carbon within terrestrial environments, but these are not within the current scope of the urban Melbourne EEA.
[49] This is distinct from the net annual addition which considers carbon emitted/removed, including carbon losses due to disturbances such as fire and harvesting. By focusing solely on additions to carbon stocks, the gross (and net) sequestration approach fails to capture the contribution ecosystems make by storing carbon over time (see carbon retention approach).

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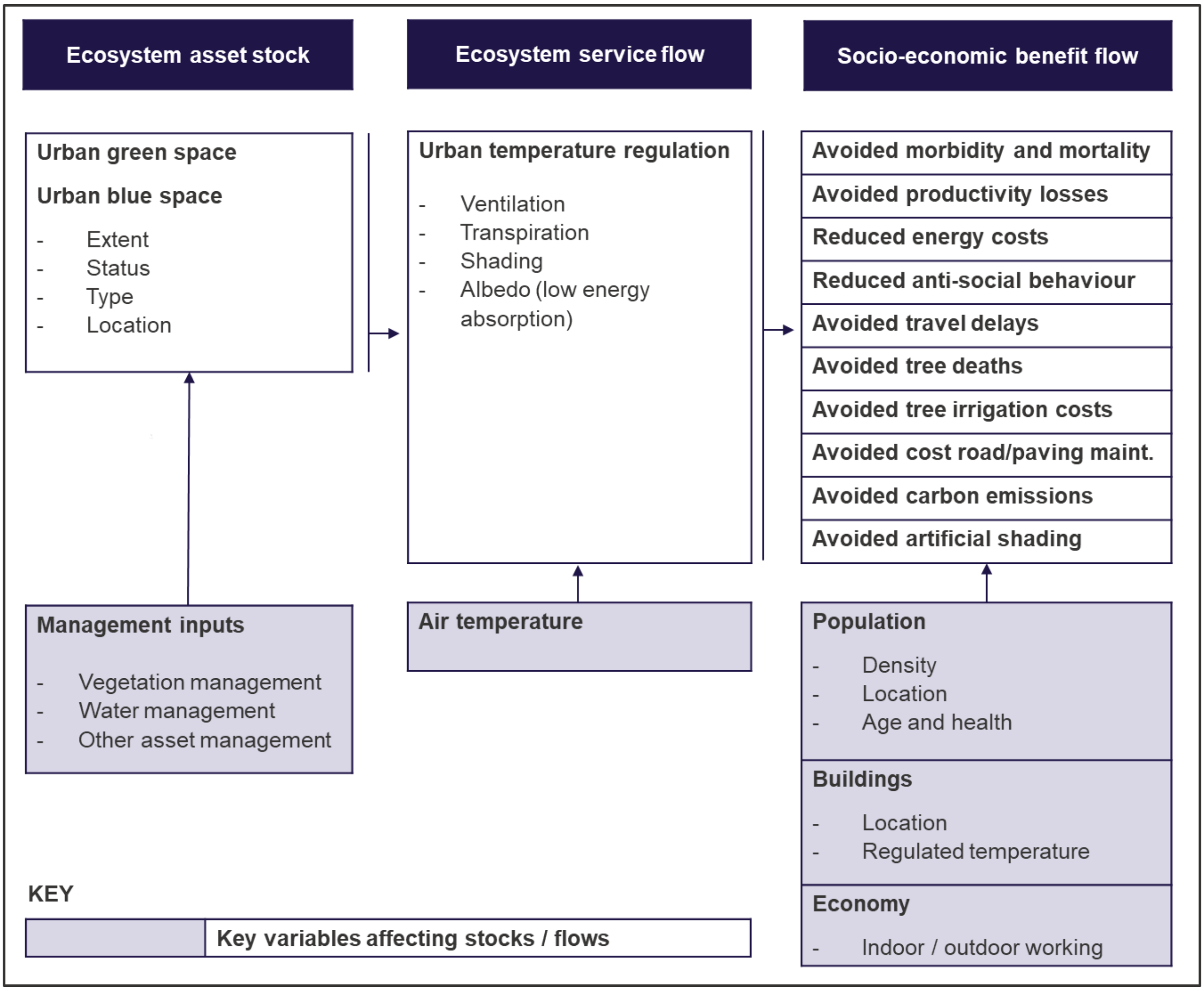
urban ecosystem assets leads to physical and mental health and wellbeing benefits, as well as financial benefits, that can be quantified and valued using economic analysis for inclusion in an environmental-economic account.

Figure 4.6.1. sets out the logic chain linking the ecological functioning of urban ecosystem assets to the socio-economic benefits provided (note not all of these are mutually exclusive).

Figure 4.6.1. Illustrative logic chain for local climate regulating service of green-blue infrastructure



For the purposes of this initial assessment, the focus is on the avoided incidence of ill-health (morbidity) and deaths (mortality) and avoided productivity losses as a result of the urban cooling provided by green-blue infrastructure. These socio-economic benefits were chosen because they are currently resulting in the greatest costs associated with extreme heat in Melbourne (see Annex 10, Section A10.5.) and therefore are expected to be the most highly valued benefits from urban cooling by green-blue infrastructure.

4.6.1. Physical provision of local climate regulation

4.6.1.1. Methodology

Based on the literature review (see Annex 10, Section A10.5.), there is no existing estimate of how much higher the costs of extreme heat would be without the urban cooling service provided by urban ecosystem assets. Furthermore, the reviewed literature revealed that estimating the socio-economic benefits of urban cooling by ecosystem assets requires two steps. The first is to estimate the effect of urban ecosystem assets on temperatures and the second is to estimate the effect of changes in temperatures on socio-economic outcomes (health and productivity). The proposed approach to both steps is set out below and has been informed by that was developed under the UK urban natural capital account (eftec, 2015).

i) **Effect of urban ecosystem assets on air temperatures:** Based on the review of literature, the estimates of the cooling effect (ºC) of different urban ecosystem assets that are used in this Melbourne EEA are set out in Table 4.6.1., specifically for trees, parks and blue infrastructure (e.g. rivers, streams, lakes and ponds).

Table 4.6.1. Proposed cooling effect (ºC) of different urban ecosystem assets for use in Melbourne study

Ecosystem type	Cooling effect (ºC)	Sources	Justification
Canopy cover / street trees	0.7ºC	CRCWSC (2017)	This is the average cooling effect of a single tree on a hot day (upper bound 1.2°C) and a tree lined street on a hot day (lower bound 0.2°C) in Melbourne.
Urban parkland	1.1ºC	Al-Gretawee et al. (2016)	This is a Melbourne specific estimate. To apply in the urban environmental-economic account, the figure estimated by Al-Gretawee et al. (2016) of 4.3°C figure needs to be adjusted to get the effect on average maximum temperatures throughout the day. The study team proposes to make an adjustment of 25% on the basis that the cooling effect estimated by Al-Gretawee et al. (2016) is occurring for approximately 25% of the duration of maximum temperatures within a day (i.e. 2 hours out of 8 hours, between 10am and 12pm). This results in an estimated reduction in average maximum temperatures in Melbourne of 1.1°C.
Blue infrastructure	1ºC	Hathway & Sharples (2012)	Although not Melbourne specific, this value is deemed suitable for an indicative estimate. Considered appropriate to apply beyond just rivers to all blue infrastructure within Melbourne.

The detailed approach to apply the cooling effects in Table 4.6.1. to estimate the aggregate reduction in temperature across the urban Melbourne EEA area is set out in Annex 10, Section 10.5. This estimates the average change across the entire EEA area by assuming the total cooling effect of ecosystem assets from the literature (Table 4.6.1.) occurs in proportion to the percentage of total land within the EEA area that is covered by ecosystem assets.[50] This will not account for the cooling effects of parks, trees and blue infrastructure beyond their boundaries.

[50] For example, the estimated cooling effect from the literature would occur across all of Melbourne if the urban EEA was covered entirely by green-blue infrastructure and half of the estimated cooling effect would occur across all of Melbourne if half of the land area was green-blue infrastructure.

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The assessment then estimates the increase in the number of single days per year at different (lower) peak daily temperatures (°C) above 30°C in Melbourne due to the presence of ecosystem assets. To do this, historical peak daily temperature information is utilised from a central Melbourne weather station which makes the analysis at an aggregate level relatively straightforward (compared to developing and piecing together separate analyses for different geographic areas across Melbourne).

To estimate what peak temperatures would have been in 2019 without the existence of ecosystem assets, the single combined cooling effect (°C) for all of the ecosystem assets in Melbourne is applied to the historical peak daily temperatures. This method assumes the number of days at each temperature band is evenly distributed within that temperature band and adds the temperature differential to the current distribution of single days within that temperature band so that these days move into the next (hotter) temperature banding. So, if the estimated temperature change due to green-blue infrastructure was 0.5°C then half of the days at each peak temperature would shift into the next temperature band, if it were 1°C then *all* the days at each peak temperature would shift into the next temperature band, if it were 2°C then all days would shift forward *two* temperature bands (i.e. two degrees centigrade). This will provide estimates of the change in the number of days at different peak temperatures in Melbourne in 2019 under a 'with GBI' scenario (actual 2019 peak temperatures) compared to a 'without GBI' scenario (2019 peak temperatures adjusted by the combined cooling effects).

ii) **Effect of temperature on health outcomes (morbidity and mortality):** Analysis of the historical relationship or 'dose-response function' between the incidence of human morbidity and mortality and temperatures (°C) for the geographic area of interest can be used to estimate the effect of changes in temperature due to urban ecosystem assets on health outcomes (morbidity and mortality). Based on the review of literature (see Annex 10.5 for more detail), the estimates of the dose-response functions linking changes in temperatures to changes in morbidity and mortality in Melbourne that are used in this Melbourne EEA are set out in Table 4.6.2.

Table 4.6.2. Linkages between health outcomes and increased temperatures in Melbourne (AECOM, 2012)

Health outcome		Incidence	Unit
Mortality	Additional mortality due to heat	0.08	Per 100,000 persons per day per 1 degree above 30°C
Morbidity	Additional ambulance attendance due to heat related morbidity	0.09	Per 100,000 persons per day per 1 degree above 30°C
	Additional emergency department presentations due to heat related morbidity	0.52	Per 100,000 people aged 64-74years, per day per 1 degree above 30°C
		3.82	Per 100,000 people aged 74+ years, per day per 1 degree above 30°C

The AECOM (2012) dose-response functions (Table 4.6.2.) are reported per 100,000 persons and in some instance for specific age brackets (i.e. 64-74 years old and above 74 years old) and so it is necessary to identify the exposed population. DELWP Victoria in Future 2019 Population and Household Projections (2019) provides a breakdown of population by age group and can be used to identify an estimate of the total population within the urban area of the assessment boundary in 2019, as well as an estimate of the population who is aged between 64-74 years and over 74 years.

The estimated population within the urban Melbourne EEA boundary has been calculated from Victoria in Future 2019 (DELWP, 2019) population estimates by Statistical Area 2 (SA2) boundaries. SA2s are the smallest boundary resolutions for which population estimates are available, however these do not perfectly align with the assessment boundary. To adjust the estimates to better reflect the population with the urban Melbourne EEA boundary, the area of 'urban' landcover in the assessment boundary (from the extent analysis, see Section 3.1.2), is taken as a proportion

Unofficial

of the total urban area within the broader SA2 combined boundary (of 90 per cent, which means that 90 per cent of the urban area that exists within SA2 areas intersect with the rural-urban interface), and then applied to the population estimate (i.e. the population within the interface area is calculated as 90 per cent of the population at SA2 level).

The estimates of the elderly population within the urban Melbourne boundary are calculated by applying the proportion of specific age brackets in the Melbourne Greater Capital City Statistical Area (GCCSA) from DELWP (2019) to the total population estimated to exist within the urban Melbourne EEA boundary.

Estimates of the change in the incidence of morbidity and mortality in Melbourne due to changes in number of days at different peak temperatures were then estimated by applying the dose-response functions from the literature (Table 4.6.2.) to the change in number of days at different peak temperatures (from Step (i)) and the beneficiary population from DELWP (2019) data.

4.6.1.2. Results

i) Effect of urban ecosystem assets on air temperatures

The estimated aggregate effect of ecosystem assets on temperatures (°C) across urban Melbourne in 2019 is -0.23°C as shown in Table 4.6.3., with the extent of the urban ecosystem assets illustrated in Figure 4.6.2.

Table 4.6.3. Estimated aggregate effect of ecosystem assets on temperatures (°C) across urban Melbourne in 2019

Asset type		Extent (Ha)		% total EEA area	Cooling differentials for assets (°C)	Estimated cooling effect across Melbourne (°C)
Blue infrastructure		2,794	Ha	1%	-1.0	-0.01
Green infrastructure	Highly managed assets	31,892	Ha	15%	-1.1	-0.16
	Green roofs	19	Ha	0%	-1.1	-
	Street trees	15,810	Ha	7%	-0.7	-0.05
Total urban Melbourne asset extent		214,378	Ha			**-0.23**

The estimated temperature differential due to the existence of urban ecosystems of -0.23°C is used to estimate the number of days at each temperature under a "without ecosystems" scenario compared to a “with ecosystems” scenario (i.e. the current situation within urban Melbourne), see Table 4.6.4.

This leads to an estimated shifting in the number of days that are experienced at temperatures above 30°C (under the current “with vegetation” scenario, based on BoM temperature data from the Melbourne Olympic Park site for 2019) towards higher temperatures (under a “without vegetation” scenario). Because of the way the method has been devised (see Section 4.6.1.1.), there is a fall in the number of days at certain temperatures under a “with vegetation scenario” despite the overall pattern towards higher temperatures under a without ecosystem asset scenario, see Table 4.6.4.[51]

[51] This happens for a given temperature banding (e.g. 30°C), where the number of days shifting into that temperature banding (due to the absence of vegetation) is estimated to be less than the number of days shifting from that temperature banding into a hotter temperature banding.

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Figure 4.6.2. Extent of urban ecosystem assets with cooling effects within urban Melbourne EEA region

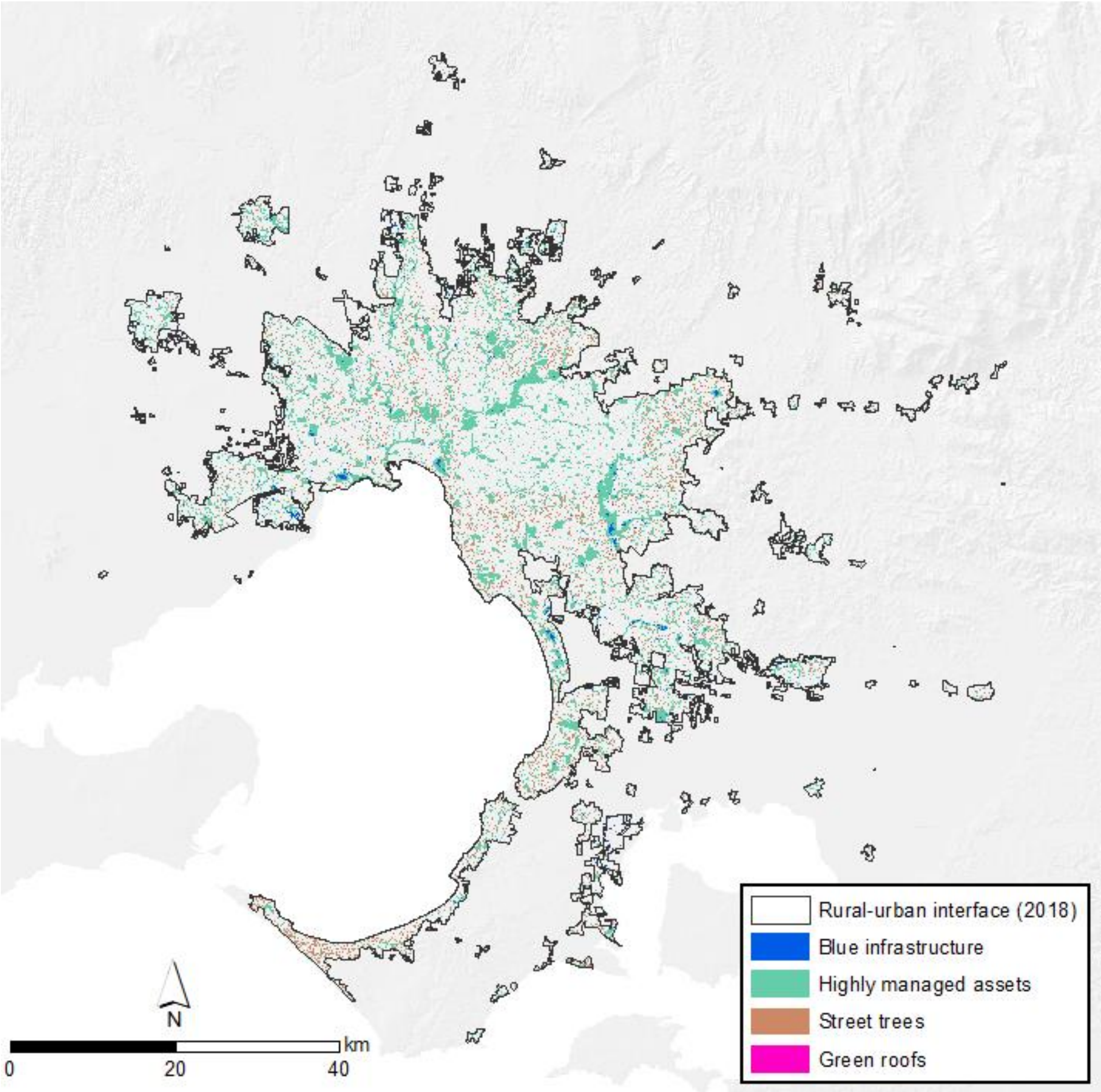

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Table 4.6.4. Change in the number of single days per year at different peak daily temperatures (ºC) in Melbourne due to the presence of GBI

Peak daily temperature (°C)	CBD (Melbourne Olympic Park) in 2019		
	Total number of single days per year "with ecosystems"	Estimated **total** number of days at each temp. under a "without ecosystems" scenario	Estimated change in the number of days at each temperature under a "without ecosystems" scenario
30	7	6.5	-0.5
31	1	2.4	1.4
32	3	2.5	-0.5
33	3	3.0	0.0
34	6	5.3	-0.7
35	0	1.4	1.4
36	4	3.1	-0.9
37	0	0.9	0.9
38	4	3.1	-0.9
39	0	0.9	0.9
40	4	3.1	-0.9
41	0	0.9	0.9
42	2	1.5	-0.5
43	1	1.2	0.2
44	0	0.2	0.2

ii) Effect of temperature on health outcomes (morbidity and mortality)

The estimated incidence per 100,000 people per day per degree centigrade at different peak temperatures is estimated by extrapolating out the incidence rate from AECOM across temperatures up to 44°C (there were no days above 43°C in Melbourne in 2019 but the method adopted assumes a shift in the number of days towards hotter peak temperatures, so a proportion of the days at 43°C will shift to 44°C), see Table 4.6.5.

Peak daily temp. (°C)	Estimated incidence per 100,000 people per day at peak temp's			
	Additional mortality (excess deaths) due to heat	Additional ambulance attendance due to heat related morbidity	Additional emergency department presentations due to heat related morbidity	
			64-74years old	74+ years old
30	0.08	0.09	0.52	3.82
31	0.16	0.18	1.04	7.64
32	0.24	0.27	1.56	11.46
33	0.32	0.36	2.08	15.28
34	0.4	0.45	2.6	19.1
35	0.48	0.54	3.12	22.92
36	0.56	0.63	3.64	26.74
37	0.64	0.72	4.16	30.56
38	0.72	0.81	4.68	34.38
39	0.8	0.9	5.2	38.2
40	0.88	0.99	5.72	42.02
41	0.96	1.08	6.24	45.84
42	1.04	1.17	6.76	49.66
43	1.12	1.26	7.28	53.48
44	1.2	1.35	7.8	57.3

Table 4.6.5. Estimated incidence per 100,000 people per day at peak temperatures (°C) (based on AECOM, 2012)

Unofficial

The estimated population within the geographic boundary of the urban Melbourne is estimated to be 4.5 million, consisting of 390,000 of 64 to 74 year old's and 280,000 over 74 year old's, as shown in Table 4.6.6. The estimates of population within the urban Melbourne EEA area are calculated on a per 100,000 basis (see Table 4.6.6.) in order to apply the estimated incidence rates for adverse health outcomes associated with extreme heat at different temperatures from AECOM (2012).

Table 4.6.6. Estimated population within the urban Melbourne EEA boundary

	Urban Melbourne population in 2019		
	Total	**Population divided by 100,000**	**% of total**
Total	4,515,306	45	
64-74 years old	387,518	4	8.6%
74> years old	281,968	3	6.2%

The estimated change in adverse health outcomes across the Melbourne population is then estimated by applying the dose-response functions (from Table 4.6.5.) to the estimated population divided by 100,000 (from Table 4.6.6.) to get to a Melbourne population specific estimated change in the incidence of adverse health outcomes due to heat for every day above 30°C, see Table 4.6.7. (see Annex 10, Section A10.5. for more information).

The Melbourne population specific estimates of changes in the incidence of adverse health outcomes for each day above 30°C (Table 4.6.7) is then applied to the estimated change in the *number of days* above 30°C due to the presence of ecosystem assets (relative to a "without vegetation" counterfactual), see Table 4.6.8.

Table 4.6.7. Estimated total incidence of adverse health outcomes per day at peak temperatures (°C)

Peak daily temp. (°C)	**Estimated total incidence per day at peak temp's**			
	Additional mortality (excess deaths) due to heat	Ambulance attendance due to heat related morbidity	Emergency department presentations due to heat related morbidity	
			64-74years old	74+ years old
30	4	4	2	11
31	7	8	4	22
32	11	12	6	32
33	14	16	8	43
34	18	20	10	54
35	22	24	12	65
36	25	28	14	75
37	29	33	16	86
38	33	37	18	97
39	36	41	20	108
40	40	45	22	118
41	43	49	24	129
42	47	53	26	140
43	51	57	28	151
44	54	61	30	162

Unofficial

Peak daily temp. (°C)	Estimated additional total incidence under a "without green infrastructure scenario" in 2019 *(0.23 degrees increase in temperature)*			
	Additional mortality (excess deaths) due to heat	Ambulance attendance due to heat related morbidity	Emergency department presentations due to heat related morbidity	
			64-74years old	74+ years old
30	-2	-2	-1	-5
31	10	11	6	30
32	-5	-6	-3	-15
33	0	0	0	0
34	-12	-14	-7	-37
35	30	33	17	89
36	-23	-26	-13	-69
37	26	30	15	79
38	-30	-33	-17	-89
39	33	37	18	98
40	-36	-41	-20	-108
41	40	45	22	118
42	-21	-24	-12	-64
43	12	13	6	34
44	12	14	7	37
Total	**33**	**37**	**18**	**98**

Table 4.6.8. Estimated additional total incidence of adverse health outcome under a "without green infrastructure scenario" in 2019

Unofficial

The estimated additional total incidence of adverse health outcomes associated with extreme heat under a "without ecosystem scenario" in 2019 that is avoided under a “with ecosystem” scenario as follows, see Table 4.6.8:

- 33 additional deaths due to extreme heat that are avoided due to the existence of ecosystems.

- 37 additional ambulance attendances due to extreme heat that are avoided due to the existence of ecosystems;

- 18 additional emergency department presentations by 64 to 74 year old’s due to extreme heat that are avoided due to the existence of ecosystems;

- 98 additional emergency department presentations by over 74 year old’s due to extreme heat that are avoided due to the existence of ecosystems;

Table 4.6.9. summarises the uncertainty associated with these results and shows that there is a high uncertainty associated with these estimates. This is because of a reliance on single sources of evidence regarding the relationship between green-blue infrastructure and adverse health outcomes, along with the combination of assumptions that have been adopted in order to develop a Melbourne-wide estimate.

Unofficial

Table 4.6.9. Uncertainty assessment - physical provision of local climate regulation

	Uncertainty in…		
	Evidence	**Assumptions**	**Total**
Explanation	- The location specific nature of any cooling effect due to green-blue infrastructure and the wide number of variables affecting this, means that applying a specific temperature differential across a large area is subject to significant uncertainty. - Reliance on single sources of evidence on the cooling effect of different ecosystem assets, with Melbourne specific estimates used for trees and parks and a UK specific estimate used for blue infrastructure. - Reliance on single sources of Melbourne specific evidence on the dose-response effect that cooling has on adverse health outcomes. - The assessment estimates the effect of urban rivers, lakes, ponds, wetlands as well as parks and gardens, street trees and green roofs. It does not include the existence of broader ecosystem assets within the urban Melbourne EEA area including urban shrubland, grassland, forest / woodland, coastal margin and farmland which together total 37,263ha out of the 214,378ha of the urban Melbourne EEA area. - This assessment estimates the effect of urban cooling on adverse health outcomes and productivity only. It does not include other socio-economic benefits of green infrastructure's urban cooling such as avoided energy costs, tree deaths, travel delays, tree irrigation, road and pavement maintenance costs and artificial shading.	- To estimate the average change across the entire Melbourne EEA area by assuming the total cooling effect of ecosystem assets from the literature occurs in proportion to the percentage of total land within the EEA area that is covered by ecosystem assets. - The number of days at each temperature band is assumed to be evenly distributed within that temperature band and the estimated Melbourne-wide temperature differential (due to green-blue infrastructure) is added to the current distribution of single days within that temperature band so that these days move into the next (hotter) temperature banding. So, if the estimated temperature change due to green-blue infrastructure was 1°C then all the days at each peak temperature would shift into the next temperature band.	High
Rating	3	3	9

4.6.2. Monetary value of local climate regulation

4.6.2.1. Methodology

Based on the literature reviewed (see Annex 10, Section A10.5.) the approach taken to valuing the socio-economic benefits delivered by local climate regulating effect of green-blue infrastructure are as follows:

- **Value of avoided adverse health outcomes (morbidity and mortality):** The most relevant unit values ($ per incident) for use to estimate the avoided costs of adverse health outcomes due to the local climate regulating effect of urban ecosystem assets in Melbourne are set out in Table 4.6.10., based on the most relevant sources identified from the literature review (see Annex 11, Section A11.6.). This includes Australian Government figures for the value of mortality (value of statistical life) and Dept. of Health and Productivity Commission estimates for the value of morbidity (costs of ambulance and hospital services)

Table 4.6.10. Unit values ($ per incident) of adverse health outcomes due to heat in Melbourne

Health outcome		Value	Unit	Year	Measure	Source
Mortality	Additional mortality (excess deaths) due to heat	$5.1m[52]	$ per incident	2019	Value of statistical life	Dept. of PM and Cabinet (2019)
Morbidity	Additional ambulance attendance due to heat	$1,358[53]	$ per incident	2019	Cost of ambulance	Dept. of Health (2019)
	Additional emergency department presentations due to heat	$5,235[54]	$ per incident	2019	Cost of hospital services	Productivity Commission (2009)

The avoided cost of adverse health outcomes due to the local climate regulating effect of urban ecosystem assets in Melbourne is estimated by applying the unit values in Table 4.6.10. to the estimated change in health outcomes under the 'with urban ecosystem assets' compared to the 'without urban ecosystem assets' scenario for Melbourne from the assessment of physical provision of local climate regulating service (see Section 4.6.1.).

- **Value of avoided productivity losses:** Productivity is measured through Gross Value Added (GVA). The value of (avoided) productivity losses due to local climate regulating effect of urban ecosystems can therefore be measured through estimated changes in Gross Value Added (GVA).

  Based on the review of literature (see Annex 10, Section A10.5. for more detail), the estimates of the dose-response functions linking changes in temperatures to changes in productivity in Melbourne that are used in this Melbourne EEA are set out in Figure 4.6.3. Whilst the literature suggests that productivity losses begin to occur above 25ºC (CRCWSC, 2019), productivity losses for this urban Melbourne account will be estimated for temperatures above 30ºC. The number of days (above a peak temperature above 30°C) for which there are certain percentage changes (improvements) in labour productivity in Melbourne due to urban cooling by green-blue infrastructure is estimated by applying the dose-response functions from the literature on changes in productivity at different temperatures (Figure 4.6.3.) to the estimated change in number of days at different peak temperatures above 30°C (see Table 4.6.4. and Annex 11, Section A11.5.).

  Figure 4.6.3. shows the loss of worker productivity in Melbourne is estimated to start at a reduction of 0.6 per cent at 25ºC, extending to 25 per cent for a 36ºC day. Survey results did not record any temperatures higher than 36ºC given that the survey was undertaken in May and October, so linear extrapolation has been used to extend the data beyond 36ºC. For the purpose of this indicative assessment, it is proposed the actual data for temperatures between 30ºC and 36ºC be used and that after 36ºC the impacts on productivity remain at 25 per cent (rather than using the extrapolated trend line estimated in CRCWSC, 2019).

[52] Updated to 2021 dollars from $4.9 million using CPI adjustment from June 2019 to June 2021 for All groups CPI, Australia.

[53] Updated to 2021 dollars from $1,265 using CPI adjustment from June 2019 to June 2021 for Medical and hospital services, Australia.

[54] Updated to 2021 dollars from $4,876 using CPI adjustment from June 2019 to June 2021 for Medical and hospital services, Australia.

Figure 4.6.3. Estimated relationship between productivity and maximum daily temperatures (CRCWSC, 2019)

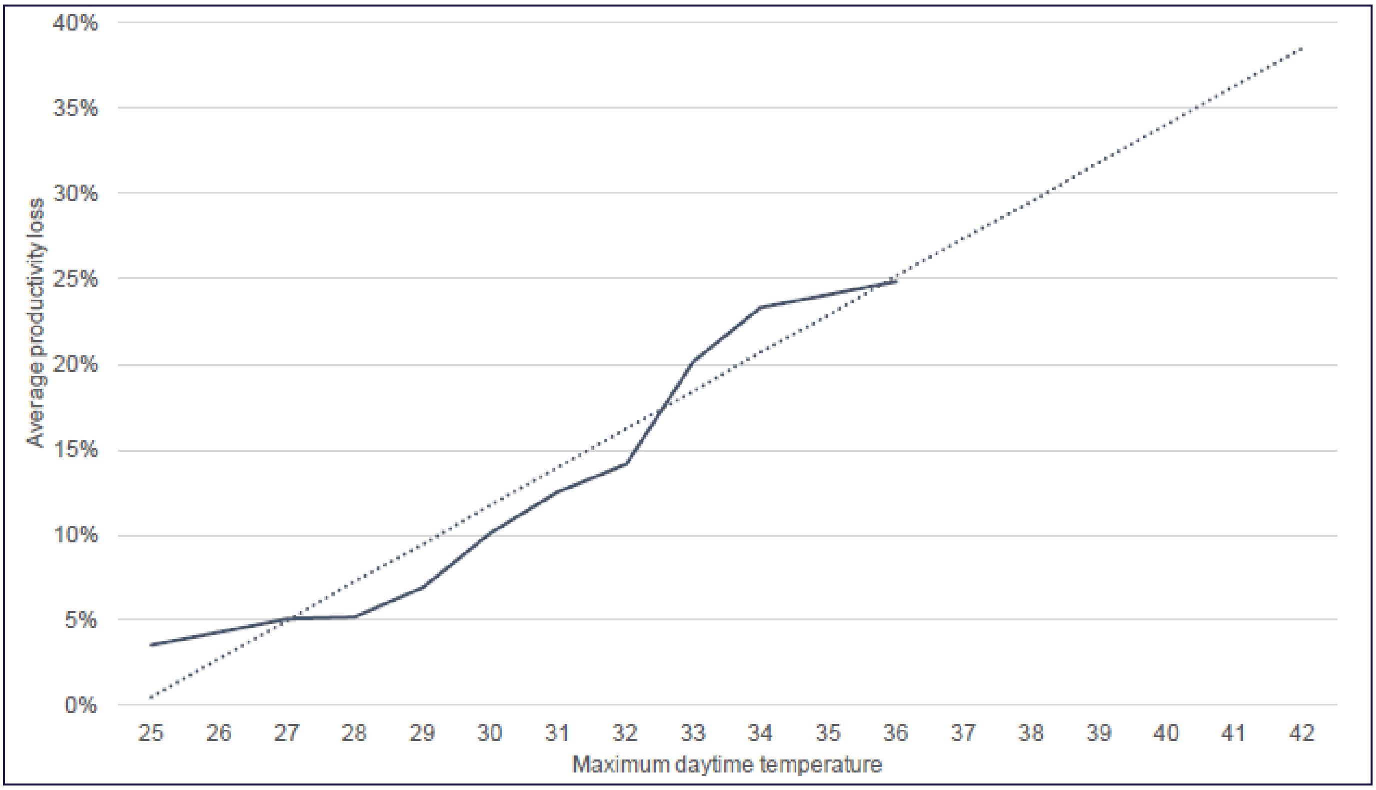


Table 4.6.11. sets out the approach adopted to apply the estimated percentage change in productivity due to the cooling effect of urban ecosystem assets to estimate the value of avoided productivity losses.

Table 4.6.11. Proposed method to value the avoided productivity losses associated with local climate regulation by urban ecosystem assets within Melbourne urban assessment boundary

Step	Method
1. Estimate daily GVA for the urban area within the assessment boundary.	Annual GVA estimates from the ABS will be identified using REMPLAN for the region that aligns most closely with the urban EEA area. This figure will then be converted into a daily average figure. This will not align with the urban area within the assessment boundary (GVA estimates for the actual urban area within the assessment boundary could be commissioned from REMPLAN, which would require a budget). Therefore, to identify the economic output within the urban area of the assessment boundary the total is adjusted based on the proportion of commercial and industrial property area that exists within the urban area relative to the total commercial and industrial area within the assessment boundary as a crude approach.
2. Estimate the proportion of the economy that is affected by extreme heat.	CRCWSC (2019) acknowledge that it is a proportion of jobs across the economy (not the entire economy) that will be affected by daytime maximum temperatures, either because some jobs will be in air-conditioned offices or otherwise unaffected by daytime temperatures (such as evening jobs). In the absence of guidance on this matter, the CRCWSC (2019) study "conservatively assumes (productivity in) 20 per cent of jobs are affected by daytime heat." This crude approach is deemed to be appropriate for the purpose of this assessment, to estimate an indicative value.
3. Estimate the avoided loss of GVA due to the cooling effect of GI	Apply the estimated number of days (above a peak temperature above 30°C) for which there are certain percentage changes in labour productivity in Melbourne (see Figure 4.6.3.) to the estimated daily GVA for the urban area for the proportion of the economy that is assumed to be vulnerable to extreme heat (from Step 2).

4.6.2.2. Results

The estimated value of adverse health outcomes associated with extreme heat under a "without ecosystem scenario" in 2019 that is avoided under a "with ecosystem" scenario is estimated at $168 million (see Table 4.6.12.).

Table 4.6.12. Estimated value of adverse health outcomes due to heat in Melbourne under a "without ecosystem scenario" in 2019 (0.23 degrees increase in temperature)

Health outcome	Estimated additional total incidence under a "without green infrastructure scenario"	Unit values ($ per incident) of adverse health outcomes due to heat in Melbourne	Total value of adverse health outcomes due to heat in Melbourne
Additional mortality (excess deaths) due to heat	33	$5.1m	$167m
Ambulance attendance due to heat related morbidity	37	$1,358	$0.05m
Emergency department presentations due to heat related morbidity (64 year old's and over)	116	$5,235	$0.6m
Total			**$168m**

The value of avoided productivity losses due to local climate regulating effect of urban ecosystems is measured through estimated changes in Gross Value Added (GVA) in urban Melbourne.

In order to estimate the impact to economic value due to the absence of urban ecosystem assets, the daily productivity vulnerable to extreme heat within urban Melbourne has been estimated as $95 million, detailed in Table 4.6.13.

Table 4.6.13. Productivity value vulnerable to extreme heat within urban Melbourne EEA region

Details	Value	Source
Total value-added estimate for metropolitan Melbourne	$346,808m[55]	REMPLAN, 2020
Daily value-added estimate for metropolitan Melbourne	$950m	
The proportion of commercial and industrial property area that exists within the urban area relative to the total commercial and industrial area within the assessment boundary	50 per cent	Victorian Land Use Information System (LU 2 and 3 classes), 2017
Daily value-added estimate for urban Melbourne EEA area	$475m	
The proportion of the economy that is affected by extreme heat	20 per cent	CRCWSC, 2019
Daily value-added estimate for the urban Melbourne EEA area that is vulnerable to the effects of extreme heat	$95m	

Applying this daily productivity estimate that is vulnerable to the effects of extreme heat to the "without ecosystem scenario" in 2019 (0.28 degrees increase in temperature) yields an estimated annual change in economic value of $5 million per year (see Table 4.6.14.). In other words, the gain in productivity due to the presence of green-blue infrastructure and its cooling effect is estimated to be worth $5 million per year.

[55] Updated to 2021 dollars from $335,130.6 million using CPI adjustment from June 2019 to June 2021 for All groups CPI, Australia.

Table 4.6.14. Estimated annual change in economic value due to the absence of urban ecosystem assets

Peak daily temp. (°C)	**Estimated impact on productivity (%)**	**Daily productivity vulnerable to extreme heat**	*Annual change in days without GBI (increase of 0.23°C)*	*Annual change in economic value (increase of 0.23°C)*
30	10%	95,049,361	-0.5	$1m
31	13%	95,049,361	1.4	-$3m
32	14.5%	95,049,361	-0.5	$1m
33	20.0%	95,049,361	0.0	-
34	23.0%	95,049,361	-0.7	$3m
35	24.0%	95,049,361	1.4	-$6m
36	25.0%	95,049,361	-0.9	$4m
37	25.0%	95,049,361	0.9	-$4m
38	25.0%	95,049,361	-0.9	$4m
39	25.0%	95,049,361	0.9	-$4m
40	25.0%	95,049,361	-0.9	$4m
41	25.0%	95,049,361	0.9	-$4m
42	25.0%	95,049,361	-0.5	$2m
43	25.0%	95,049,361	0.2	-$1m
44	25.0%	95,049,361	0.2	-$1m
Total				**-$5m**

Unofficial

Table 4.6.15. summarises the uncertainty associated with these results and shows that the monetary value of local climate regulation provide by green-blue infrastructure in Melbourne EEA region is highly uncertain. This is driven in part by the uncertainty associated with the underlying physical estimates but also due to the uncertainty associated with the proportion of the economy that is vulnerable to extreme heat and the adjustment in GVA that is needed to estimate a figure for the Melbourne EEA region specifically.

Table 4.6.15. Uncertainty assessment - monetary value of local climate regulation

	Uncertainty in…		
	Evidence	**Assumptions**	**Total**
Explanation	- The monetary estimates are reliant upon the physical estimates of changes in temperatures due to the presence of green-blue infrastructure and the associated effects on adverse health outcomes which are highly uncertain. - The evidence on the value-of a statistical life is based on Commonwealth estimates and the costs associated with morbidity are based on market data. - The estimated value of productivity is based on the GVA for Melbourne from REMPLAN, which has been adjusted to the Melbourne EEA area based on the proportion of commercial and industrial property area that exists within the urban area relative to the total commercial and industrial area within the assessment boundary, which is a crude and highly uncertain approach.	- The proportion of the economy that is vulnerable to extreme heat is assumed to be 20 percent based on CRCWSC (2019) and is highly uncertain.	
Rating	3	3	9

4.6.3. Supply and use of local climate regulation

Households, government and industry all benefit from / are users of the local climate regulating service provided by ecosystems within the urban Melbourne region. Households benefit from the improved health (avoided costs) they gain from urban cooling, industry benefits from avoided productivity losses whilst government benefits from the improved health of the population (and therefore avoiding their share of medical costs), as captured in Table 4.6.16.

In order to distribute the estimated avoided medical costs ($168 million per year) between government and households, the average split of total medical costs to households and government in 2018-19 of 68 per cent government ($114 million per year), 32 per cent households ($54 million per year) is used (households includes all private sources including private health insurers as these are funded by households) (Australian Institute of Health and Welfare, 2020).

Table 4.6.16. Supply and use table for recreation within the urban ecosystems of Melbourne

		Metric	Household	Government	Industry	Ecosystems
Local climate regulation	Supply	Additional mortality / yr				33
		Additional morbidity / yr				153
	Use	Additional mortality / yr	33			
		Additional morbidity / yr	153			
Local climate regulation	Supply	$ AUD (2021) / yr				$173m
	Use	$ AUD (2021) / yr	$54m	$114m	$5m	

4.6.4. Discussion

Urban ecosystem assets including urban parks, gardens, green roofs, street trees, rivers and lakes regulate temperature and humidity, including through ventilation and transpiration (EEA, 2018). The estimated costs of extreme heat to the economy and wider community, that is exacerbated by the urban heat island effect, would be higher without urban Melbourne's ecosystem assets that are embedded into the urban fabric.

The local climate regulating service of ecosystem assets in the urban Melbourne EEA region is estimated through the reduction in number of days at high temperatures (above 30 degree centigrade) and valued based on the avoided adverse health impacts and productivity losses. The analysis estimates:

- An estimated aggregated effect of ecosystem assets (urban rivers, lakes, ponds, wetlands as well as parks and gardens, street trees and green roofs) on temperatures (°C) across urban Melbourne in 2019 of -0.23°C.

- 33 additional deaths due to extreme heat that are avoided due to the existence of ecosystems.

- 37 additional ambulance attendances due to extreme heat that are avoided due to the existence of ecosystems.

- 18 additional emergency department presentations by 64 to 74 year old's due to extreme heat that are avoided due to the existence of ecosystems.

- 98 additional emergency department presentations by over 74 year old's due to extreme heat that are avoided due to the existence of ecosystems.

- The estimated value of adverse health outcomes associated with extreme heat under a "without ecosystem scenario" in 2019 that is avoided under a "with ecosystem" scenario is estimated at $168 million.

- The gain in productivity due to the presence of green-blue infrastructure and its cooling effect is estimated to be worth $5 million per year.

There is significant uncertainty associated with the adopted approach and resulting estimates. The location specific nature of any cooling effect due to green-blue infrastructure and the wide number of variables affecting this, means that applying a specific temperature differential across a large area is subject to significant uncertainty. Estimating the impact of any cooling effect on the population in terms of avoided adverse health outcomes and productivity is also location specific and whilst effort has been made to tailor the analysis to Melbourne, this relies on single sources of evidence that are applied broadly across the geographic area of interest.

The analysis does not include the existence of broader ecosystem assets within the urban Melbourne EEA area including urban shrubland, grassland, forest / woodland, coastal margin and farmland which together total 37,263 hectares out of the 214,378 hectares of the urban Melbourne EEA area.

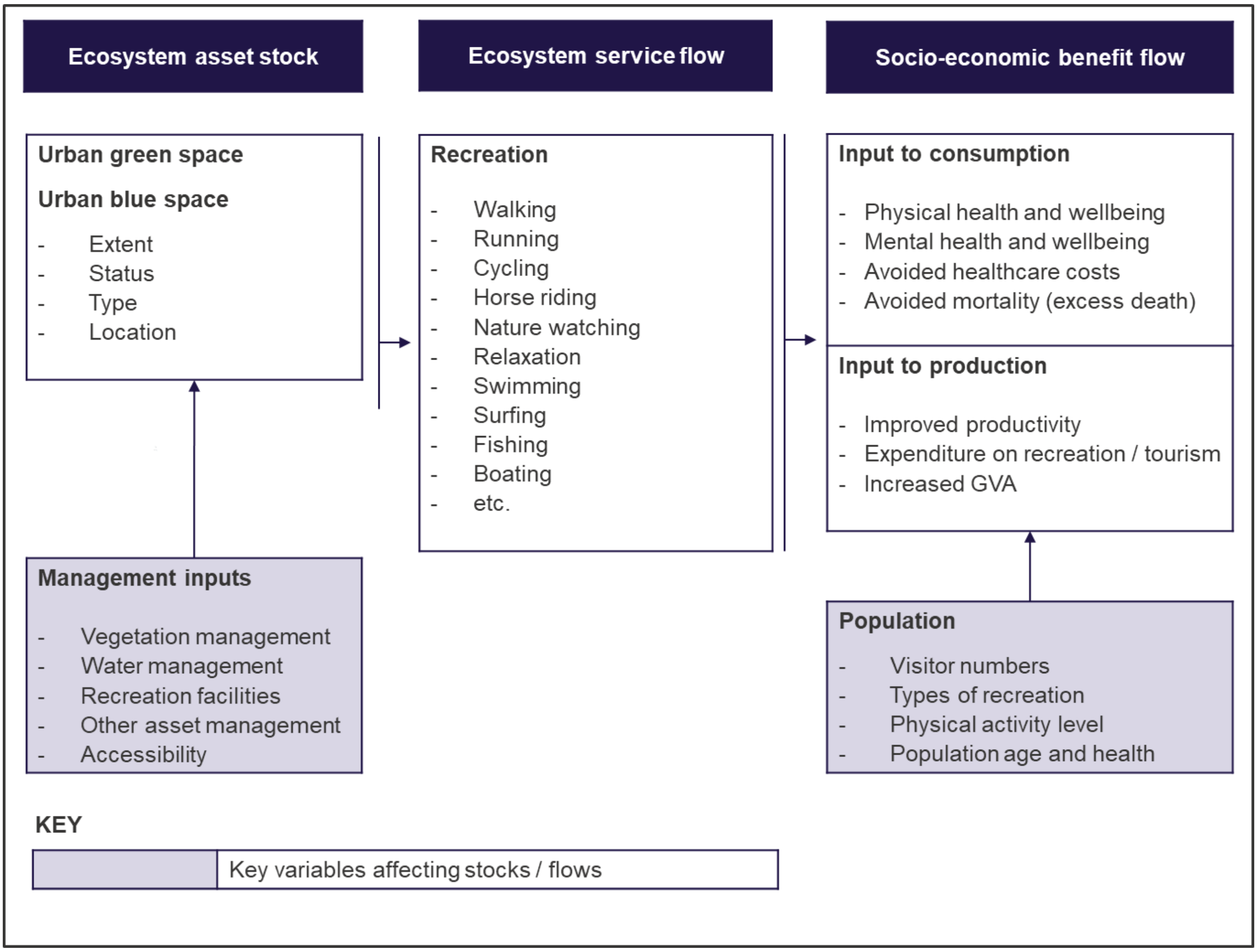
The values are estimated using justifiable assumptions based on limited evidence and should be interpreted as useful order-of-magnitude estimates that provide a proof-of-concept for how the ecosystem service of local climate regulation can be assessed in the urban Melbourne context. Consideration of how the approach could be refined in the future is set out in Section 5.4.

4.7. Recreation

Urban parks, gardens, beaches, bathing water, rivers and lakes provide society with the opportunity for "activities promoting health, recuperation or enjoyment through active, immersive, passive or observational interactions" (EEA, 2018). This includes using the environment for sport and recreation; using nature to help stay fit; watching plants and animals where they live and using nature to de-stress (EEA, 2018). These "recreational activities" lead to physical and mental health and wellbeing benefits, as well as financial benefits, that can be quantified and valued using economic analysis for inclusion in an environmental-economic account. Figure 4.7.1 sets out the logic chain linking the ecological functioning of urban ecosystem assets to the recreational opportunities and associated socio-economic benefits provided (note not all of these are mutually exclusive).

Unofficial

Figure 4.7.1. Illustrative logic chain for recreational opportunities from green-blue infrastructure



4.7.1. Physical provision of recreation

4.7.1.1. Methodology

The physical provision of recreation from ecosystem assets is captured through recreational participation in ecosystem specific activities. This can be measured in environmental-economic accounts through numbers of visits, visitors, incidences or participation hours per year to different ecosystem assets by (where possible) type of recreational activity (walking, running, sailing, boating, birdwatching etc.) including "active" visits (which meet certain activity guidelines which link to health benefits) and "passive" visits.

Based on the literature review (see Annex 10, Section A10.6.), the following approach is taken to estimating the physical provision of recreation from ecosystem assets within the urban Melbourne EEA boundary:

- **Parks Victoria data:** Parks Victoria provided the latest information on visits to their assets including:
  - Visitor Number Monitor for 2020/21 which has survey-based data for 2018/19 on total annual visits to *all* major metropolitan parks (which includes Albert Park, Jells Park and Yarra Bend Park), bays (which includes Port

Phillip Bay which is of relevance to this urban Melbourne EEA) and piers (which includes St Kilda Pier which is of relevance to this urban Melbourne EEA).
- Annual vehicle count data for Park Victoria sites within urban Melbourne EEA boundary for 2018 and 2018/19;
- Estimated annual visitor numbers for St Kilda pier in 2015 based on video monitoring data.

- **Royal Botanic Gardens Victoria visitation data:** The Royal Botanic Gardens Victoria Annual Report 2018-19 has visitor numbers for 2018-19 for Melbourne botanic gardens and Cranbourne gardens which are situated within the urban Melbourne EEA boundary.

- **Estimating "active" visits to the urban Melbourne EEA region based on type of nature based recreational activity**: "active" recreation visits are visits that meet certain physical activity guidelines (and therefore provide a health and productivity benefit). Estimating "active" visits (from total visits) enables economic valuation of the avoided health costs and productivity benefits associated with improved health outcomes due to recreation in the urban Melbourne region (see monetary valuation section). An estimated 18 per cent of visits to the parks within urban Melbourne are classified as active visits based on Parks Victoria Visitor Number Monitor survey where exercising / fitness was the specific activity most likely to be undertaken during visits to major metropolitan parks for 18 percent of visits. Active visits are estimated for parks only.

Consideration was given to the use of pedestrian count data from the City of Melbourne which monitors footfall across the city. However, the study team decided against including these estimates in the urban Melbourne EEA because the data is not capturing visits that are specific to the urban natural environment and it is not possible to reasonably estimate this. Whilst one counter does exist within a park setting at Birrarung Marr, this is the main thoroughfare from Flinders Street Station to the Melbourne sports precinct (i.e. where the MCG, AAMI park and Rod Laver Arena) and has an estimated 4.02 million pedestrians counted in 2018, significantly more than any other estimate for a specific park or garden from the data obtained by the study team from Parks Victoria and Royal Botanic Gardens. In this case it may be that the Birrarung Marr park is not being "visited" for its recreational value and although pedestrians may derive some value from walking through the park on their way to their destination, the extent to which that is true is unclear (i.e. no valuation evidence exists for this).

4.7.1.2. Results

A partial estimate of the number of visits to a selection of ecosystem assets within urban Melbourne is 7.4 million per year, as shown in Table 4.7.1. This only includes visits to seven parks, one pier and the botanic gardens and is therefore an underestimate of the total number of recreational visits to urban ecosystems in Melbourne.

Table 4.7.1. Partial estimate of nature-based recreational visits per year to urban Melbourne in 2018-19

Asset	Name	Estimated visits per year	Year	Source
Park	Braeside Park	480,171	2018	Parks Victoria vehicle count data (pers. comm. Michelle Rose, Parks Victoria)
	Brimbank Park	414,722	2018	
	Jells Park	896,894	2018/19	
	Lysterfield Park	805,982	2018/19	
	Point Nepean NP	590,416	2018/19	
	Westerfolds Park	511,366	2018/19	
	Yarra Bend	588,250	2018	
Pier	St Kilda pier	831,803	2015	Parks Victoria (2015)
Garden	Melbourne botanic garden	2,064,986	2018-19	Royal Botanic Gardens Victoria (2019)
	Cranbourne botanic gardens	246,746	2018-19	
Total (partial)		7,431,336	2018-19 [a]	-

[a] This assumes that the 2015 data on visits to St Kilda pier are representative of the year 2018-19.

A partial estimate of the number of active visits to parks over the 2018-19 year is 771,804, as shown in Table 4.7.2. The number of active visitors (i.e. one visitor might undertake multiple visits to urban parks within Melbourne in a year) is estimated to be 64,317 per year based on an assumption of 12 visits per visitor per year from DELWP and Parks Victoria (2015).

Table 4.7.2. Partial estimate of the number of active nature-based recreational engagement per year to urban Melbourne in 2018-19

Asset	Estimated active engagements per year		Year	Source
	Visits	Visitors		
Parks	771,804	64,317	2018-19	Parks Victoria vehicle count data (pers. comm. Michelle Rose, Parks Victoria). Parks Victoria Visitor Number Monitor 2020/21. DELWP and Parks Victoria (2015)

Table 4.7.3. summarises the uncertainty associated with these results and shows that the uncertainty of the estimates is high, because although the site specific information is considered to be robust, the total number of nature-based recreational visits in urban Melbourne is an underestimate.

Ecosystem assets with potentially significant numbers of nature-based visits that are either partially or totally within the urban Melbourne boundary but are not included within this analysis include Albert Park, Port Phillip Bay and Frankston and Mornington Piers.

Table 4.7.3. Uncertainty assessment - physical provision of recreation

	Uncertainty in…		
	Evidence	Assumptions	Total
Explanation	- There is limited evidence on nature based visits to sites within the urban Melbourne boundary.	- A partial estimate of total nature-based visits in urban Melbourne is made based on the available evidence where the attribution of visits to engagement with nature is considered to be clear. - It is assumed that 18% of park visits are active based on data from Parks Victoria. - It is assumed that there are 12 visits per visitor per year from DELWP and Parks Victoria (2015). - The site specific information used is considered to be robust, but an underestimate of the total number of nature-based recreational visits in urban Melbourne.	High
Rating	3	3	9

The Parks Victoria Visitor Number Monitor for 2020/21 is not used to estimate nature based visits in urban Melbourne because the data is survey-based and so whilst the aggregate data at Melbourne metropolitan region (which is wider than the urban Melbourne EEA boundary) is robust, it is not reliable at a site-level and so estimates for the specific parks, bays and piers that fall within the urban Melbourne EEA boundary cannot be reliably estimated (pers. comm. Michelle Rose, Parks Victoria). Some of the key insights from the aggregated data is still presented as it provides useful insights and context regarding the extent to which the current estimates of visits to urban ecosystems within Melbourne could be underestimated:

- **Parks**: 29.5 million visits to a major metropolitan Melbourne park in 2018-19. The most visited park was Albert Park (20 per cent) followed by Jells Park (12 per cent) and Yarra Bend Park (9 per cent).
- **Bays:** 80.4 million visits to one of Melbourne's three bays (Port Phillip, Corio and Western Port) in 2018-19. The most visited bay was Port Phillip (77 per cent).
- **Piers**: 32.9 million visits to piers in 2018-19. The most visited pier was St Kilda pier (12 per cent), followed by Frankston pier and Mornington pier (both 8 per cent).

4.7.2. Monetary value of recreation

4.7.2.1. Methodology

Based on the literature review (see Annex 11, Section A11.7.) which includes existing estimates of the value of socio-economic benefits of all nature-based recreation within Victoria (i.e. not just in urban ecosystems), there is existing data and analyses that can be drawn on to estimate the monetary value ($AUD) of recreation that is supported by ecosystem assets within the urban Melbourne region in a number of ways.

The benefits of recreation supported by the ecosystem assets of urban Melbourne accrue to the visitors themselves (input to consumption) and to nearby suppliers of tourism and recreational facilities (input to production), to the extent that they can attribute their operation to the ecosystem (UN, 2014). In this way, environmental-economic accounts are interested in all visits to ecosystem assets within the urban Melbourne EEA boundary, not just those that support the tourism industry but also (for example) visits to parks by locals which is valued by those individuals. For the purpose of this initial urban account, urban ecosystem related tourism GVA is not estimated due to the difficulty of attributing tourism GVA to the specific urban ecosystem assets that are within the EEA boundary.

A mix of approaches are used to capture different types of economic value including inputs to production and inputs to consumption, based on the reviewed literature (see Annex 11, Section A11.7.) as follows:

i) Input to consumption:

- Welfare: The Read et al (1999) value of $13[56] per visit for recreation in metropolitan parks is used in multiple studies reviewed (DELWP and Parks Victoria, 2015 and NCEconomics, 2019) and is applied directly to the number of recreational visits to parks and gardens.[57] The application of the estimated welfare value of a metropolitan park visit to the Royal Botanic Gardens is likely to be conservative given the unique features of the gardens, but is considered to be appropriate for the purpose of this initial urban Melbourne EEA.[58] The estimated welfare value of $3[59] per visit to port and coastal facilities from the Read et al (1999) study is applied to visits to piers within the urban Melbourne EEA region.

- Direct avoided (medical) costs due to physical inactivity is estimated in the Medibank (2008) study to be **$115[60] per person per year**. This will be applied to "active" visits to ecosystem assets in the urban Melbourne EEA region as set out in Table 4.7.4.

[56] Updated to 2021 dollars from $7.19 using CPI adjustment from June 1998 to June 2021 for All groups CPI, Australia.
[57] This approach is adopted because it covers the welfare value associated with all visits not just "active visits" (i.e. the annual per visit welfare value (which is separate to the avoided costs) associated with avoided burden of morbidity and mortality from Medibank (2008) only covers "active visits" and these visits could be isolated for separate valuation in the future).
[58] Read et al (1999) also estimate welfare values for recreation in historic reserves ($12 per visit) and natural features reserves ($13 per visit) which the Melbourne Royal Botanic Gardens could be classified as.
[59] Updated to 2021 dollars from $1.54 using CPI adjustment from June 1998 to June 2021 for All groups CPI, Australia.
[60] Updated to 2021 dollars from $86 using CPI adjustment from December 2007 to June 2021 for All groups CPI, Australia.

Unofficial

Table 4.7.4. Proposed method to estimate avoided medical costs due to recreation in Melbourne's parks using the approach adopted by DELWP and Parks Victoria (2015)

Step	Method
1. Estimate the total annual number of recreation park visits where primary purpose is physical exercise	Divide the total number of annual visits to urban parks within assessment boundary (from Parks Victoria) by the percentage of visits to metropolitan parks where primary purpose is physical exercise of 18 per cent (from Parks Victoria).
2. Estimate the number of "active" recreation visitors (not visits) to urban parks in Melbourne	Divide the total number of recreation visits to metropolitan where primary purpose is physical exercise (Step 1) by the average number of visits per visitor to urban parks of 12 per person per year (from DELWP and Parks Victoria, 2015).
3. Estimate the contribution of park exercise to minimum recommended level of physical activity (physical flow)	Multiply total number of "active" visitors (Step 2) by the percentage contribution of urban parks to the minimum recommended level of physical activity (DELWP and Parks Victoria, 2015) of 11 per cent.
4. Estimate the value of the contribution of park exercise to avoided direct medical costs [a]	Multiply the proportion of "active" visitor health that is attributable to park recreation (Step 3) to the direct avoided (medical) costs of physical inactivity of $115 per person per year (from literature – Medibank, 2008).

[a] The DELWP and PV (2015) study applied another step to reflect the proportion of all visitors that would not undertake physical activity in the absence of the park. This was done by applying a proportion to the total avoided health costs based on the proportion of inactive (sedentary) people in Australia (56% from VicHealth, 2016). This step is not being pursued for the Melbourne account because the purpose of account is to capture the *total* value of outdoor recreation in urban parks, not contemplate alternative behaviour / use of substitutes (e.g. gyms or parks outside of assessment boundary) to undertake physical recreation under a "no natural capital" baseline (i.e. environmental-economic accounting is different from cost-benefit analysis). This is consistent with GDP accounts which capture the total value of consumption of goods and services. The DELWP and PV (2015) estimates are therefore deemed to be underestimates of the current value of park recreation.

ii) Input to production:

- Improved productivity: direct loss of productivity due to physical inactivity is estimated in the Medibank (2008) study to be **$611[61] per employee per year** (i.e. not accounting for indirect and induced effects of this loss of productivity) and this is the figure used in MJA (2016). The application of these annual figures to a single domestic "active" visit (i.e. that meets physical activity guidelines) to ecosystem assets in the urban Melbourne EEA boundary is executed following the approach taken by DELWP and Parks Victoria (2015) through the steps in Table 4.7.5.

[61] Updated to 2021 dollars from $458 using CPI adjustment from December 2007 to June 2021 for All groups CPI, Australia.

Unofficial

Table 4.7.5. Proposed method to estimate avoided productivity losses due to recreation in Melbourne's parks using the approach adopted by DELWP and Parks Victoria (2015)

Step	Method
1. Estimate the total annual number of recreation park visits where primary purpose is physical exercise	Divide the total number of annual visits to urban parks within assessment boundary (from Parks Victoria) by the percentage of visits to metropolitan parks where primary purpose is physical exercise of 18 per cent (from Parks Victoria).
2. Estimate the number of "active" recreation visitors (not visits) to urban parks in Melbourne	Divide the total number of recreation visits to metropolitan where primary purpose is physical exercise (Step 1) by the average number of visits per visitor to urban parks of 12 per person per year (from DELWP and Parks Victoria, 2015).
3. Estimate the contribution of park exercise to minimum recommended level of physical activity (physical flow)	Multiply total number of "active" visitors (Step 2) by the percentage contribution of urban parks to the minimum recommended level of physical activity of 11 per cent (DELWP and Parks Victoria, 2015).
4. Estimate the value of the contribution of park exercise to avoided direct medical costs [a]	Multiply the proportion of "active" visitor health that is attributable to recreation (Step 3) to the productivity losses of physical inactivity of $611 per person per year (Medibank, 2008) that are avoided.

[a] The DELWP and PV (2015) study applied another step to reflect the proportion of all visitors that would not undertake physical activity in the absence of the park. This was done by applying a proportion to the total avoided health costs based on the proportion of inactive (sedentary) people in Australia (56% from VicHealth, 2016). This step is not being pursued for the Melbourne account because the purpose of account is to capture the *total* value of outdoor recreation in urban parks, not contemplate alternative behaviour / use of substitutes (e.g. gyms or parks outside of assessment boundary) to undertake physical recreation under a "no natural capital" baseline (i.e. environmental-economic accounting is different from cost-benefit analysis). This is consistent with GDP accounts which capture the total value of consumption of goods and services. The DELWP and PV (2015) estimates are therefore deemed to be underestimates of the current value of park recreation.

4.7.2.2. Results

The partial estimate of the monetary value of nature-based recreation in the urban Melbourne EEA region is approximately $91 million per year for the 7.4 million visits to a selection of ecosystems assets (seven parks, a pier and two botanic gardens) as set out in Table 4.7.6., consisting of:

- The partial estimate of the welfare value of nature-based recreation within the urban Melbourne EEA region is estimated to be $86 million a year in 2019, including $54 million per year to seven parks, $29 million per year to Melbourne botanic garden and $2 million per year to St Kilda pier.

- The partial estimate of the avoided direct medical costs due to nature-based physical activity within the urban Melbourne EEA region is estimated to be $1 million a year in 2019.

- The partial estimate of the avoided loss of productivity due to nature-based physical activity within the urban Melbourne region is estimated to be $4 million a year in 2019.

Table 4.7.6. Partial estimate of the value of nature-based recreation in urban ecosystems in Melbourne

Description of value		Asset	Estimated value ($/yr)				Year	Source
			Engagements (No./yr)	Unit value	Contribution to physical health (%)	Total value ($/yr)		
Input to consumption	Welfare	**Parks**	4,287,801	$13 / visit	n/a	$54m	2018-19	Read et al (1999)
		Gardens	2,311,732	$13 / visit	n/a	$29m		
		Piers	831,803	$3 / visit	n/a	$2m		
	Avoided medical costs	**Parks**	64,317	$115 / visitor[a]	11%	$1m		Medibank (2008)
Input to production	Improved productivity			$611 / visitor[a]		$4m		
Total						**$91m**		

[a] This represents the total cost of physical inactivity. This value is multiplied by the estimated percentage contribution of urban parks to the minimum recommended level of physical activity of eleven per cent (DELWP and Parks Victoria, 2015). The resulting value is then applied to each active visit to estimate the total value.

Table 4.7.7. summarises the uncertainty associated with these results and shows that the monetary estimates rely on the underlying visitation data that has been estimated for the urban Melbourne EEA (from the physical flow account) which is highly uncertain and there is some uncertainty associated with the economic valuation for welfare, productivity and medical costs due to the underlying studies being outdated. The overall uncertainty rating for the monetary value of recreation to the urban Melbourne EEA region is therefore high.

Table 4.7.7. Uncertainty assessment - monetary value of recreation

	Uncertainty in…		
	Evidence	**Assumptions**	**Total**
Explanation	- The monetary valuation relies on the estimate of visitation to the urban Melbourne region (from the physical flow account) which is partial and uncertain. - There is existing economic valuation for welfare associated with recreational trips to coastal facilities and metropolitan parks in Victoria from 1999 which is outdated but the most relevant information for this account. The application to botanic gardens is considered to be conservative given the unique features of these gardens. - The productivity and medical costs of physical inactivity are from 2008 which is outdated but the most relevant information for this account.	- The values for welfare, avoided productivity and medical costs assume that the Read et al (1999) and Medibank (2008) estimates are directly applicable to the urban Melbourne region.	
Rating	3	2	6

4.7.3. Supply and use of recreation

Households, government and industry all benefit from / are users of recreational opportunities provided by ecosystems within the urban Melbourne region. Households benefit from the enjoyment (welfare) and improved health (avoided costs) they gain from recreational activities, industry benefits from the avoided productivity losses whilst government benefits from the improved health of the population (and therefore avoiding their share of medical costs), as captured in Table 4.7.8.

In order to distribute the estimated avoided medical costs ($0.8 million per year) between government and households, the average split of total medical costs to households and government in 2018-19 of 68 per cent government ($0.5 million per year), 32 per cent households ($0.3 million per year) is used (households includes all private sources including private health insurers as these are funded by households) (Australian Institute of Health and Welfare, 2020).

Table 4.7.8. Supply and use table for recreation from the urban Melbourne EEA region

		Metric	Household	Government	Industry	Ecosystems
Recreation	Supply	Visits / yr				7.2m
	Use	Visits / yr	7.2m			
Recreation	Supply	$ AUD (2021) / yr				$91m
	Use	$ AUD (2021) / yr	$86m	$0.5m	$4m	

4.7.4. Discussion

The ecosystem assets of urban Melbourne provide an opportunity for recreation. The physical provision of recreation from ecosystem assets is captured through recreational participation in ecosystem specific activities.

The partial estimate of visits that can be attributed to the existence of ecosystems within the urban Melbourne EEA region is 7.4 million per year in 2018-19. Approximately a third of these visits are estimated to be to the Royal Melbourne botanic gardens (2.1 million per year). This only includes visits to seven parks, one pier and two botanic gardens and is therefore an underestimate of the total number of recreational visits to urban ecosystems in Melbourne Approximately 770,000 of these visits are estimated to be "active visits" that meet certain physical activity guidelines (and therefore provide a health benefit) undertaken by around 65,000 visitors (i.e. the same people visiting urban ecosystems for physical exercise multiple times a year).

The economic value of recreation in the urban Melbourne EEA region is approximately $91 million a year in 2018-19 based on the estimated:

- Welfare value of recreation within the urban Melbourne EEA region of $86 million in 2018-19.
- Improved productivity of the labour force from "active visits" of $1 million in 2018-19.
- Avoided medical costs to households and government of $4 million in 2018-19 from "active visits" in 2018-19.

The productivity benefits (to industry) and avoided medical costs (to government and households) are deemed to be suitable to add to the welfare value because these are different (indirect) outcomes / benefits to the (direct) wellbeing benefit of engaging with the natural environment.

These partial values are estimated using justifiable assumptions based on limited evidence and should be interpreted as useful order-of-magnitude estimates that provide a proof-of-concept for how the ecosystem service of recreation can be assessed in the urban Melbourne context. See Section 5.4 for consideration of how the approach could be refined in the future.

4.8. Cultural value

4.8.1. Historic and contemporary cultural heritage

Ecosystem assets within urban Melbourne include places, landscapes and features that have traditional historical heritage value (e.g. shipwrecks) or contemporary cultural value (e.g. arboreal Avenues of Honour) to different groups (note that the treatment of cultural value to Traditional Owner people is treated separately, see Section 4.8.2).

Where information exists on specific ecosystem features with a historic or contemporary cultural value, this will be captured in the ecosystem condition account under "socio-economic characteristics - cultural assets" which reports on the status of key cultural assets within the urban Melbourne EEA region (see Table 3.2.1 and Figure3.2.14.). The cultural service provided by these cultural assets could be measured in the future, for example through deliberative engagement with communities regarding the importance of these cultural heritage assets to them.

4.8.2. Traditional Owners living cultural heritage

There is no standard process for incorporating Traditional Owners cultural values into the UN System of Environmental-Economic Accounts, it is an area of ongoing work internationally. Including any information on the value of Traditional Owners living cultural heritage within this urban Melbourne environmental-economic account requires consultation with the Traditional Owner Groups of the lands that are within the accounts' geographic boundary (DELWP State-wide Heritage Management Co-ordinator) which is out-of-scope of this initial urban Melbourne environmental-economic account.

4.9. Existence / Option value

Society benefits from knowing that ecosystem assets that are not currently "used" (with "use" being defined in a broad sense of delivering ecosystem services that are enjoyed by society) will be there in future should we need them (akin to an insurance policy), this is known as an **option value.** This could be people valuing the existence of the Royal Botanic Gardens in Melbourne because they might one day visit these gardens. Option value is particularly important for the diversity of ecosystems, species and genes (i.e. biodiversity) given the potentially significant value of nature based research providing new products (i.e. medicines and technology) as well as the need for the natural environment to be adaptable and resilient to future pressures such as climate change. Ecosystem assets, including biodiversity, also has an **existence value**, independent of society's use (also termed "intrinsic value" of nature).

There is no economic valuation evidence on the existence and option value of urban Melbourne's ecosystem assets, and it is challenging to estimate and apply such a value in a way that appropriately reflects the value that society places on this (i.e. what is the appropriate beneficiary population?). Therefore, for the purpose of this urban Melbourne EEA, it is assumed that society values the existence and option value of ecosystem assets (including biodiversity) within urban Melbourne, as evidenced by areas being protected / on Crown-land (i.e. the government acts of behalf of society to secure the future integrity of the ecosystems within the area). This effectively assumes society wants the ecosystems and biodiversity within urban Melbourne to be maintained / restored.

However, it is recognised that there are trade-offs associated with the management of urban Melbourne region for different uses (i.e. urban development) and that maintaining the current status of ecosystems might not be possible. In order to inform decision making where ecosystems / biodiversity is at risk of being lost, the metrics in the urban Melbourne EEA extent and condition accounts are used to understand what is at risk of being lost. This includes

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tracking changes in the status of rare and threatened species, habitat suitability scores, native vegetation scores etc. over time.

This information can be used to inform decisions regarding potential ways to mitigate potential effects on ecosystems / biodiversity in the urban Melbourne region, by maintaining the overall (net) level of certain metrics across the region (or within Victoria), through policies such as biodiversity offsets, relocation of rare/threatened species etc. This information can therefore be used to ensure the status of ecosystems (and biodiversity) is being secured / protected over time in order that their existence and option value is sustained into the future.

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5. Conclusions and next steps

5.1. Summary

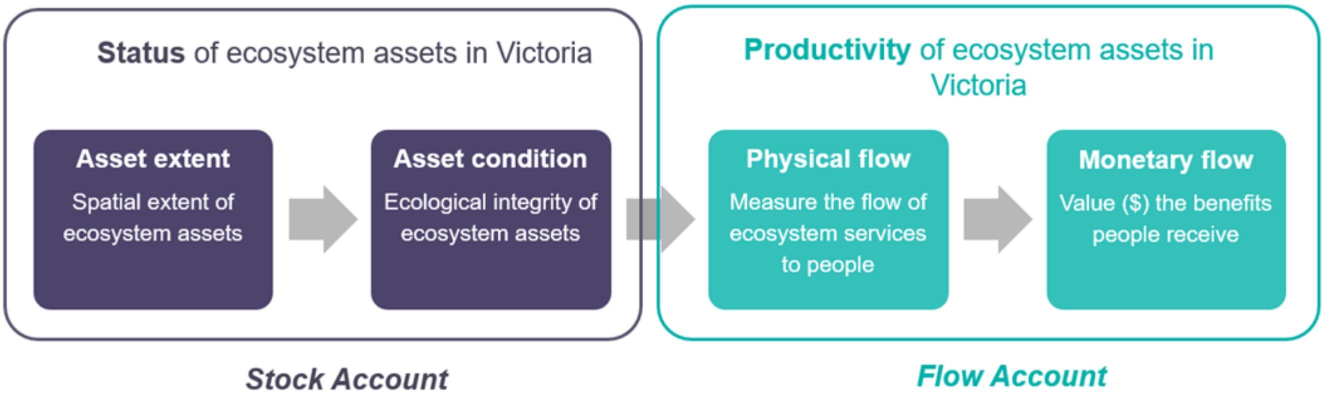
The value of green and blue infrastructure in urban environments is well established and widely acknowledged. Urban parks, market gardens, street trees, rivers and lakes provide food and recreational opportunities, as well as regulate noise, air quality and local and global climates. These environmental goods and services lead to a range of health and wellbeing benefits, as well as financial benefits, that can be quantified and valued using economic analysis.

There is a significant amount of data and analysis on the socio-economic value of green and blue infrastructure in Victoria and Melbourne, however it is not currently consolidated or articulated in a way that is useful for decision makers. Addressing this evidence gap by developing an urban Melbourne environmental-economic account was supported by DELWP's green infrastructure working group and received sign-off from DELWP's Senior Leadership Team in 2019.

This project develops a baseline environmental-economic account for urban Melbourne that aligns with the UN System of Environmental Economic Accounts – Ecosystem Accounts guidance (UN, 2021). The UN SEEA is a framework for reporting on links between the environment and the economy using internationally agreed accounting concepts.

Ecosystem accounts are a type of environmental-economic account (EEA) that take stock of current ecosystem assets – in terms of their extent, location, and condition – and quantify and value the flow of ecosystem services that these assets generate for people, who enjoy benefits from them. Figure 5.1.1. sets out the ecosystem framework. For the purpose of this work, reference will be made to the urban Melbourne environmental-economic account (urban Melbourne EEA).

Figure 5.1.1. Environmental-Economic Accounts - Ecosystem accounting framework



This environmental-economic account for urban Melbourne shows that the ecosystems within the urban Melbourne EEA boundary are important for threatened flora and fauna and deliver a range of ecosystem services that provide significant socio-economic value to society.

The methodological approach to urban Melbourne EEA development was agreed with the project steering group (DELWP's green infrastructure working group) based on a review of economic assessments of urban ecosystem assets globally, international guidance on environmental-economic accounting as well as existing information on ecosystem status and productivity within Melbourne.

Environmental-economic accounts are typically developed iteratively, with initial accounts focusing on priority areas that are subsequently expanded and refined over time. This urban Melbourne EEA has made use of the best available information at the time of the study. Given that no data has been collected specifically for the study region or for the purpose of developing an EEA, justifiable assumptions have been adopted based on data (where possible) or expert judgement in order to align readily available information with the urban Melbourne EEA boundary and with the principles of SEEA as best as possible. Based on this approach and the uncertainties associated with this, the results should be interpreted as indicative order or magnitude estimates that provide a proof-of-concept urban Melbourne EEA and a basis for future work to refine and expand the accounts to provide useful evidence on the status and productivity of ecosystem assets in the region.

The account has been developed for 2019 on the basis that this is the most recent year for which most of the necessary information exists (including the latest ecosystem extent data in Victoria) and ensures that the account is not skewed by the impact of COVID-19. Information for 2019 has been used where possible and where 2019 data is not available it is taken from the years 2015 to 2021 (some condition data precedes this but is presented for completeness). The account could therefore be more accurately described as being representative of ecosystem status and productivity over the period 2015 to 2021.

The urban Melbourne EEA region consists mostly of built-up areas / grey infrastructure (approximately 127,000 hectares or 59 per cent). The remaining approximately 88,000 hectares (or 41 per cent) consists of the natural ecosystem assets within the urban extent. Highly managed assets, including parks, open space, reserves and sports and recreation assets, make up the largest urban ecosystem asset type (approximately 32,000 hectares or 15 per cent), and integrated green infrastructure, namely street / city tree canopy, cover approximately 16,000 hectares (or 7 per cent) (refer to Table 5.1.1. for the headline extent account). The spatial distribution of the asset extent within the urban Melbourne EEA area is defined by the outer perimeter of the ‘Rural-urban interface’ (DELWP, 2018) (Figure 5.1.2.).

Key insights from the information compiled in the ecosystem condition account (refer to Table 5.1.2. for headline condition account) are:

- Native vegetation condition scores (measured from 0-100) (DELWP 2017) across the study area generally reflect the very high level of vegetation disturbance and average 8 out of 100 for the Melbourne EEA area.

- Habitat importance for threatened species is measured using ‘Strategic Biodiversity Values’ data (DELWP 2016c). The data tells a similar story to the native vegetation condition scores, with the very high level of disturbance to native vegetation being the main driver of low scores, averaging 24 out of 100 for the Melbourne EEA area.

- Data from the Victorian Biodiversity Atlas (DELWP 2021) records the observation of 111 individual species of threatened flora and 103 individual species of threatened fauna located within the urban Melbourne EEA study area.

- Vegetation cover data was sourced from the Cooling and Greening Melbourne project (DELWP 2019a) shows that vegetation cover across urban Melbourne varies significantly. The inner eastern suburbs have much higher proportions of tree coverage when compared to the newly developed areas of north-western and south-eastern Melbourne. This has implications for urban cooling capacity and amenity.

- Above ground live biomass data across Victoria’s public land areas has been created by the Victorian Forest Monitoring Program (DELWP 2018b). The data for the study area shows a stable level of biomass from 2012 until 2017 which suggests limited major disturbances within the public land estate of urban Melbourne.

- Coastal acid sulphate soils (CASS) occur naturally across large parts of Victoria’s coastline and if left undisturbed

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pose little risk to the environment and built assets. If disturbed however water draining from such sites can become highly corrosive damaging ecosystems and built assets. The Melbourne EEA study area contains 9,691 hectares of land susceptible to CASS (DJPR 2003).

- 2,474 hectares of land within the urban Melbourne EEA study area is classified as highly susceptible to landslide (DJPR and A.Miner 2017). The highest risk locations are concentrated around the Hastings area which comprises just 1.3% of the total urban Melbourne EEA study area.

- The Victorian Index of Stream Condition (ISC) (DELWP 2010) shows that within the urban Melbourne EEA study area 81% of the streams and rivers were in poor to very poor condition, 19% in moderate condition and no streams were in good or excellent condition. The mean urban Melbourne EEA study area 2010 ISC score was 6 out of 50.

- The Victorian Index of Estuary Condition (IEC) (DELWP 2021b) shows that of the 19 estuaries within the urban Melbourne EEA study area none were in good or excellent condition, 3 were in moderate condition, 11 were in poor condition and 5 were in very poor condition.

- Within the urban Melbourne EEA study area there are 213 flood water retarding basins that collectively cover 986 hectares (Melbourne Water, 2019).

- The urban Melbourne EEA study area stored 5.5 million tonnes of carbon in 2019 (DISER 2021), the more heavily vegetated eastern suburbs and vegetated river corridor's providing the bulk of that storage.

- Light pollution is commonly expressed using the Bortle scale, a nine level numeric scale that measures the night sky's brightness through visibility of celestial objects with level 1 being a true dark sky with no interference through to 9 being a typical inner city location where only the brightest stars are visible. The majority of the urban Melbourne EEA study area is class 7 with the Melbourne CBD class 9.

- Data showing the percentage of houses within 400 metres of open space (AUO, 2020) shows much variation across the urban Melbourne EEA study area. Eastern, northern and far eastern Melbourne have relatively low access to open space with large areas displaying less than twenty percent of all houses within 400 meters of open space.

- Analysis of data from the Victorian Heritage Database (DELWP 2019c) shows that there are 907 recorded historic cultural heritage sites that wholly or partly intersect with open space within the urban Melbourne EEA study area.

- The urban Melbourne EEA study area intersects with three Designated Water Supply Catchment areas totalling 73 hectares, all within the Greenvale Reservoir area (DELWP, 2018c).

- There are three Ramsar listed wetlands within or intersecting the urban Melbourne EEA study area (Edithvale-Seaford Wetlands, Port Phillip Bay {western shoreline} and Western Port. (DEE, 2017).

- Within or intersecting the urban Melbourne EEA study area there are 26 individually named National Parks or Nature Conservation Reserves totalling just over 600 hectares.

- Within the urban Melbourne EEA study area there are 35 public piers and jetties (DELWP, 2020) providing recreational opportunities for fishing, swimming, site seeing, nature observation and boating.

- Within the urban Melbourne EEA study area there are 101 public boat access points such as ramps, slipways and launches (DELWP, 2020) providing recreational opportunities for sailing and boating.

- Within or immediately adjacent to the urban Melbourne EEA study area there are 77 individually classified boating restriction zones totalling approximately 3,659 hectares (DELWP, 2020).

- There are 894 kilometres of walking tracks and 1,107 kilometres of bicycle paths within the urban Melbourne EEA study area (DELWP 2021d).

Key insights from the information compiled in the flow accounts include (refer to Table 5.1.3. for the headline physical and monetary values estimated for each ecosystem service):

- The analysis undertaken for the urban Melbourne EEA suggests that the ecosystems of the region deliver ecosystem services that are worth at least $300 million per year, with an alternative estimate suggesting that the ecosystem services could be worth at least $1.6 billion per year. The (at least) $300 million estimate excludes the amenity valuation as this estimate potentially captures values from other ecosystem services, including those which have been assessed as part of this account. The alternative estimate of (at least) $1.6 billion combines the valuations of amenity and global climate regulation, as the global climate regulation service is the only assessed ecosystem service that does not specifically provide benefits on a localised scale, thus the benefits of the global climate regulating services of ecosystem assets would not factor into the value that local residents place on green space that is captured in the estimated house price premiums associated with proximity to green space.

- The "amenity" value of green infrastructure is estimated to be the most highly valued ecosystem service. However, it is unclear precisely what "bundle of ecosystem services" are captured within this approach and caution needs to be used when using this "amenity" value alongside other estimates of the value of ecosystem services from urban ecosystem assets in Melbourne. The estimated amenity value of metropolitan parks within the urban Melbourne EEA region is estimated to be $0.5 billion per year and $1 billion per year for sports and recreation parks. This value is a demonstration of residents' willingness to pay to live closer to these particular types of parks, which will in part be determined by their ability to pay. The interpretation of this value for policy decision making needs careful consideration to avoid the conclusion that society values parks more highly in affluent areas compared to less affluent areas, and it is recommended that these results are not used as the sole measure of benefits of green space, including in any prioritisation process for comparisons of the benefits of new parks in different locations.

- Air filtration regulation service by urban trees benefits communities by reducing exposure to harmful pollutants which in turn improves health outcomes. There are an estimated 6.9 million trees within the urban Melbourne EEA region which remove over 1,500 tonnes of pollutants per year from the air, across the pollutants: NO_2, SO_2, PM10, CO, PM2.5 and O_3. The monetary value of pollutants removed by urban trees in a year has been estimated for NO_2, SO_2 and $PM_{2.5}$ at $6 million to $6.4 million based on damage costs related to morbidity and mortality from pollution.

- Educational visits supported by the ecosystems of the urban Melbourne EEA region are estimated to total 6,500 (or almost 300,000 student visitors) in 2019, with most frequently visited suburbs within the urban Melbourne for nature-related educational trips in 2019 were Parkville (651 visits), Melbourne (349 visits) and Brunswick East (185 visits). The monetary value of these visits are a very conservative representation of the value of these educational trips to society based on activity expenditures alone, estimated at $3.4 million per year, and not the true economic value of educational benefits associated with these trips including improved learning and life skills, mental health benefits and environmental awareness.

- Production of food biomass in the urban Melbourne EEA region is supported by ecosystems which provide a range of ecological functions that enable species to live and grow. Analysis for this urban Melbourne EEA suggests there is a substantial agricultural production within the urban Melbourne EEA region including 48,000 tonnes of arable output (crops and hay) and 155,000 livestock valued at around $8.7 million a year based on

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resource rent provided by urban ecosystems (i.e. isolating the contribution of the ecosystem from other inputs such as labour and machinery). Of this $8.7 million, $7.1 million is the contribution from the production of food, while $1.6 million is from other production such as hay, flowers or turf. The value to households of community garden production in the urban Melbourne EEA region is estimated to be worth around $60,000 per year based on avoided costs alone (i.e. not accounting for the range of other benefits of community garden production).

- Global climate regulation service is estimated based on avoided release of carbon stocks which total 20.4 million tCO_2e in the urban Melbourne EEA area. This ecosystem service is valued at between $35 million per year based on the avoided cost of greenhouse gas abatement or offset measures and $106 million per year based on the avoided damages to society (social cost of carbon).

- The local climate regulating service of ecosystem assets in the urban Melbourne EEA region is estimated through the reduction in number of days at high temperatures above 30 degrees centigrade and valued based on the avoided adverse health impacts and productivity losses. The aggregated effect of ecosystem assets (urban rivers, lakes, ponds, wetlands as well as parks and gardens, street trees and green roofs) on temperatures (°C) across urban Melbourne in 2019 is estimated at -0.23°C, which is estimated to avoid 33 additional deaths, 37 additional ambulance attendances and 116 additional emergency department presentations by 64 year old's and over due to extreme heat under a "without ecosystem scenario". - The estimated value of adverse health outcomes associated with these events is $168 million. The gain in productivity due to the presence of green-blue infrastructure and its cooling effect is estimated to be worth $5 million per year.

- The partial estimate of recreational visits that can be attributed to the existence of ecosystems within the urban Melbourne EEA region is 7.4 million per year in 2018-19. Approximately a third of these visits are estimated to be to the Royal Melbourne botanic gardens (2.1 million per year). This only includes visits to seven parks, one pier and the botanic gardens and is therefore an underestimate of the total number of recreational visits to urban ecosystems in Melbourne Approximately 770,000 of these visits are estimated to be "active visits" that meet certain physical activity guidelines (and therefore provide a health benefit) undertaken by around 65,000 visitors (i.e. the same people visiting urban ecosystems for physical exercise multiple times a year). The economic value of recreation in the urban Melbourne EEA region is approximately $91 million a year, based on the estimated:

  a) Welfare value of recreation within the urban Melbourne EEA region of $86 million in 2018-19.
  b) Improved productivity of the Australian labour force from "active visits" of $1 million in 2018-19.
  c) Avoided medical costs to Australian households and government of $4 million in 2018-19 from "active visits".

Table 5.1.4. shows the aggregated supply and use table which captures the "supply" of ecosystem services from ecosystem assets owned by different economic units and "used" by other economic units / beneficiaries. Key insights from the information compiled in the supply and use account are:

- There are significant estimated benefits provided to households (worth at least $180 million a year, with an alternative estimate suggesting it could be worth at least $1.6 billion a year with the combined estimates of amenity and global climate regulation), government (approximately $115 million a year) and industry (approximately $20 million a year).

- Households directly benefit from air filtration, global climate regulation, local climate regulation and recreation (welfare and avoided health costs), food (market price) and amenity (property premiums). Government directly benefits from local climate regulation and recreation (avoided health costs). Industry directly benefits from local climate regulation (avoided health costs), food and recreation (productivity gains and GVA) and education (expenditure / GVA). (There are also indirect benefits of these ecosystem services that flow across these "users").

The uncertainty ratings (scale of 1 (low) to 9 (high)) are shown as a guide for future work to refine the analysis that's been undertaken for this initial urban Melbourne EEA and improve its robustness for decision making. The remainder of this concluding section sets out suggested next steps to refine and expand the urban Melbourne EEA in order to further its practical use to inform decision making within the region.

Table 5.1.1. Headline extent account for urban Melbourne EEA in 2019

	Urban asset type	Narrow urban asset type	Estimate	Metric	Uncertainty
Urban asset extent	Marine		0	Hectares	Medium
	Alpine		0		
	Shrubland		1,756		
	Grassland		15,799		
	Forest / woodland		13,870		
	Coastal margins		89		
	Farmland		5,749		
	Freshwater and wetland		2,794		
	Urban	Built-up areas	126,599		
		Integrated green infrastructure	15,829		
		Highly managed assets	31,892		
	Total		**214,378**		

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Figure 5.1.2. Spatial distribution of ecosystem assets across the urban Melbourne EEA in 2019 (DELWP, 2020)

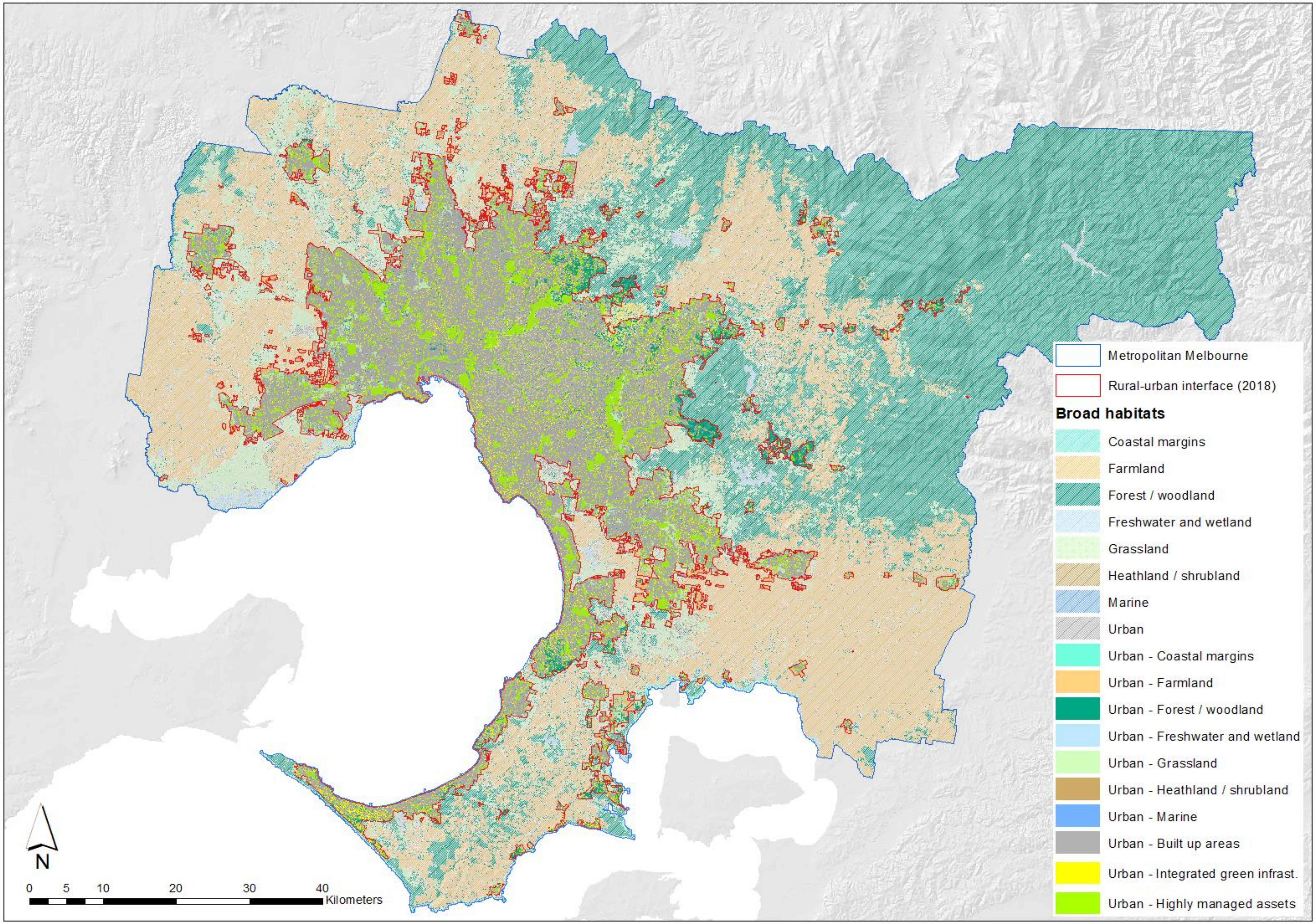

Table 5.1.2. Headline condition account for the urban Melbourne EEA area

Condition category / Indicator	Ecosystem	Primary ecosystem service being supported	Resolution	Source	Year	Metric	Condition Score Urban Melbourne EEA area	Uncertainty
Ecological condition - Biodiversity								
Native vegetation condition	Terrestrial	Existence / option value	75m grid	DELWP (2017)	2017	Score 1 -100	8	Medium
Habitat importance-threatened species	Terrestrial	Existence / option value	225m grid	DELWP (2016a)	2016	Score 1-100	24	Medium
Threatened flora	Terrestrial	Existence / option value	Point data	DELWP (2021)	2021	Species count	111	Medium
Threatened fauna	Terrestrial	Existence / option value	Point data	DELWP (2021)	2021	Species count	103	Medium
Vegetation cover	Terrestrial	Existence / option value	1:5k	DELWP (2019a)	2018	% grass	16	Medium
						% shrub	6	Medium
						% tree	14	Medium
Vegetation biomass[a]	Terrestrial	Timber/Global Climate Reg	30m grid	DELWP (2018b)	2017	Tonnes/Ha	167	Low
Apiary Sites on public land	Terrestrial	Food	Point data	DELWP (2021a)	2021	Count	1	Low
Ecological condition – Soil								
Coastal acid sulphate soil susceptibility	Any / All	Saltwater ecosystem services	1:100k	DJPR (2003)	2003	Ha	9,691	Medium
Post fire landslide susceptibility	Terrestrial	Erosion regulation	1:25k	DELWP (2016b)	2010	Ha	1	Medium
Landslide susceptibility	Terrestrial	Erosion regulation	1:250k	DJPR & A.Miner (2017)	2017	Ha (high and v.high)	2,474	Medium
Ecological condition - Water								
Stream condition (index)	Streams	Freshwater ecosystem services	1:25k	DELWP (2010)	2010	Score 0-50	6 (very poor)	Medium
Estuary condition (index)	Estuaries	Freshwater ecosystem services	1:25k	DELWP (2021b)	2021	Score 0-50	23 (poor)	Medium
Retarding basins	Terrestrial	Flood regulation	1:5k	Melbourne Water (2019)	2021	Ha	986	Low
						Count	213	Low
Ecological condition – Carbon								
Carbon stock	All	Global climate regulation	100m grid	DISER (2021)	2019	tCO^2	5,555,655	Medium
						tCO^2 / Ha	26	Medium
						tCO^2e	20,355,921	Medium
Socio-economic characteristics – Location								
Light pollution	All	Aesthetics / Recreation	350m grid	Stare (2021)	2019	Radiance	16	Low
Proximity to open space	All	Recreation	1:5k	AUO (2020)	2018	% of dwellings within 400m of public open space	57	Low
Socio-economic characteristics - Cultural assets								
Historic cultural heritage (partly or wholly within open space)	Terrestrial	Existence / Recreation	Point data	DELWP (2019c)	2019	Ha	4,026	Low
						Count	907	Low
Socio-economic characteristics - Governance and management								
Designated water supply catchment	All	Water purification	1:25k	DELWP (2018c)	2021	Ha	73	Low
						Number	3	
Ramsar Wetlands	Wetlands	Habitat provision	1:25k	DEE (2017)	2021	Ha	204	Low
						Number	3	
National parks and nature reserves	All	Various	1:25k	DELWP (2021c)	2021	Ha	601	Low
						Number	26	
Other conservation reserves	All	Various	1:25k	DELWP (2021c)	2021	Ha	3,017	Low

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						Number	139	
Piers and jetties	Marine	Recreation and Tourism	Point data	DELWP (2020)	2020	Count	35	Low
Boat access points	Marine	Recreation and Tourism	Point data	DELWP (2020)	2021	Count	101	Low
Boating restriction zones[b]	Marine	Recreation and Tourism	1:25k	DELWP (2020)	2021	Ha	3,659	Low
Walking tracks	Terrestrial	Recreation and Tourism	1:25k	DELWP (2021d)	2020	Km	894	Low
Bicycle path	Terrestrial	Recreation and Tourism	1:25k	DELWP (2021d)	2020	Km	1,107	Low

[a] Above ground biomass data available on public land only.
[b] Boating and swimming zones are prepared under the Marine Safety Act 2010 with the primary aim of providing a safe environment for recreational water users.

Table 5.1.3. Summary flow (physical and monetary) accounts for urban Melbourne EEA in 2019 with uncertainty assessment

Ecosystem service		Scope	Physical flow			Monetary flow *(present value, 2021 prices)*			
			Estimate	Metric	Uncertainty	Estimate	Metric	Valuation approach	Uncertainty
Air filtration		Urban trees	1,500	Tonnes pollutants/yr	High	$6m to $6.4m	$m/yr	Damage costs	High
Amenity		Metropolitan and sports and rec. parks	-	-	-	$1,560m [b]	$m/yr	Hedonic price	High
Education		All ecosystems	295,000	Visitors/yr	Medium	$3.4m	$m/yr	Expenditure	High
Biomass for food	Agriculture	Farmland	48,000	Tonnes/yr	High	$8.7m	$m/yr	Resource rent from market prices [a]	High
			155,000	Livestock/yr					
	Community production	Community gardens	48,000	Kg/yr	High	$0.06m	$m/yr	Resource rent from market prices [a]	High
Global climate regulation	Carbon retention	All ecosystems	20.4m	tCO2e	Medium	$35m to $106m	$m/yr	Carbon price to social cost of carbon	High
	Carbon sequestration	*4 broad ecosystems/30% Urban Melb EEA area*	*150,000*	*tCO2e*	*Medium*	*$6m to $19m*	*$m/yr*	*Carbon price to social cost of carbon*	*High*
Local climate regulation		*4 broad ecosystems/30% Urban Melb EEA area*	33	Additional mortality/yr	High	$173m	$m/yr	GVA contribution, welfare and avoided costs	High
			153	Additional morbidity/yr					
Recreation		Some parks, gardens and piers	7.2m	Visitors/yr	High	$91m	$m/yr	GVA contribution, welfare and avoided costs	High

[a] The contribution of the ecosystem to these socio-economic benefits is isolated at the monetary valuation stage in what is known as a “resource rent” calculation which strips out the contribution of other inputs (e.g., cost of human labour, machines etc) from the market price of the good / service.
[b] This is a not additive to other ecosystem services apart from global climate regulation. To do so would result in double counting.

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Table S4. Summary supply and use account

Metric		Ecosystem service	Household	Government	Industry	Ecosystems
Supply	$ AUD / yr (2021)	Air filtration				$6m - $6.4m
		Education				$3.4m
		Biomass for food				$9m
		Global climate regulation				$35m - $106m
		Local climate regulation				$173m
		Recreation				$91m
		Total				**$317m - $389m**
		Amenity				*$1,560m*
Use	$ AUD / yr (2021)	Air filtration	$6m - $6.4m			
		Education			$3.4m	
		Biomass for food	$0.06m		$9m	
		Global climate regulation	$35m - $106m			
		Local climate regulation	$54m	$114m	$5m	
		Recreation	$86m	$0.5m	$4m	
		Total	**$181m - $252m**	**$115m**	**$21m**	
		Amenity	*$1,560m*			

5.2. Links between accounts

There are a number of links that can / should be drawn across the sub-accounts of the urban Melbourne EEA and with other environmental-economic accounts, as follows:

a) Links between urban Melbourne EEA sub-accounts: Environmental-economic accounts consist of a series of linked accounts (extent, condition, physical flow and monetary flow as well as the supply and use tables) which capture information on different aspects of the natural environment. The information across all of these accounts (not just the monetary account) must be considered if a fully informed perspective of the sustainability of society's use of ecosystem assets is to be drawn (i.e. if we can expect continued flows of ecosystem services from these assets into the future).

Links can be drawn from the accounts of each ecosystem service (flow) to the account of the underlying ecosystem assets (stock) on which this flow depends. The extent, condition and spatial configuration (i.e. location) of ecosystem assets within the urban environment determine the value of the bundle of ecosystem services that these assets provide, including the value of amenity, air quality regulation, local climate regulation and educational and recreational opportunities that are assessed in this account.

For example, the number / proportion of urban residences that are in close proximity to urban ecosystem assets reveals the populations' accessibility to these assets and therefore the magnitude of the opportunity for the population to benefit from the bundle of ecosystem services that these assets provide. Proximity to green space (for example) is included as a metric in the condition account and if tracked over time can reveal changes in the overall liveability of Melbourne as a city (i.e. increases in proximity to green space is suggestive of increases in the value of the range

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of ecosystem services provided by green space (specifically those services that are reliant on the proximity of beneficiary population) and therefore of liveability).

b) Links between urban Melbourne EEA and other EEA: Whilst the focus of this initial urban Melbourne EEA is on the ecosystem assets that are located within the urban fabric, the condition and productivity of these assets is (potentially) dependent on ecosystem assets outside of the urban boundary (including but not limited to the broader Melbourne metropolitan area). Similarly, the ecosystem services produced by ecosystem assets within urban Melbourne may be "exported" to beneficiaries outside of the urban Melbourne EEA area (as well as goods and services enjoyed by Melburnians embodying some ecosystem services produced by ecosystem assets elsewhere. Future work could consider these interconnections across geographic areas and how these should be captured in environmental-economic accounts for Victoria.

Some of the value reported in the urban Melbourne EEA is already captured in the System of National Accounts, for example commercial food production is already captured in the System of National Accounts for Australia. Environmental-economic accounts draw attention to the contribution of the natural environment to economic output by isolating resource rent. EEA also capture some value that is beyond the scope of the SNA including informal food production (household production) that is not captured in national economic accounts, therefore providing a more holistic perspective of the importance of the natural environment to societal wellbeing.

The value of ecosystem services provided by urban ecosystem assets is (partly) a reflection of their management, specifically the input of human and manufactured capital. The value of these other capital inputs should be deducted from the value of ecosystem services in order to isolate the contribution of ecosystem assets (i.e. "resource rent"). This is particularly relevant for highly managed assets in urban environments which cost a lot to maintain such as parks and street trees (whereas the productivity of other ecosystems such as native forests is not necessarily reliant on other capital inputs).

For the purpose of this initial account, the contribution of other economic inputs to the value of ecosystem services produced from Melbourne's urban ecosystems is estimated and accounted for where exchange values are estimated (typically for market goods and services). Further consideration should be given to the contribution of other economic inputs (machinery, labour) to supporting values estimated using stated preference (e.g. willingness-to-pay) and revealed preference (e.g. hedonic pricing) techniques as well as exchange values for non-market benefits (e.g. avoided health costs associated with active recreation). Specific thought should be given to whether a more comprehensive estimate of resource rent could be made by developing an "expenditure account" which reports the cost of managing urban ecosystem assets (e.g. pruning street trees, planting flower beds, cutting park grass).

5.3. Use of the current Urban Melbourne account

This proof-of-concept urban account for Melbourne provides information on the status and value of the ecosystems within Melbourne. It can be used as follows (see Annex 13 for the key uses of urban EEA that were identified from the literature review):

h) As evidence of the total value of urban Melbourne's ecosystem assets to the Victorian, Australian and global economy and community and the distribution of this across the region. The analysis undertaken for the urban Melbourne EEA suggests that the ecosystems of the region deliver ecosystem services that are worth at least $300 million per year, with an alternative estimate suggesting that the ecosystem services could be worth at least $1.6 billion per year.

i) To build the business case for investment and/or alternative policies/management to maintain current ecosystem status and productivity. The sustained delivery of the estimated annual benefits from urban ecosystems is dependent on current ecosystem status to be maintained (at a minimum). The distribution of

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socio-economic value is mapped (for most ecosystem services) across the region, enabling the identification of hotspots that deliver significant value to society that could provide some prioritisation of ecosystem maintenance.

j) To assess the effectiveness of existing policy and environmental management and identify opportunities to enhance ecosystem status and productivity through future policy/management/investment. Information on the current status and productivity of ecosystems in the urban Melbourne region can be judged against policy/management targets and where performance is poor this is suggestive of the need for improvement. For example, the urban Melbourne EEA condition account suggests that the status of native vegetation (8 out of 100) and freshwater/estuaries (6 out of 50 and 23 out of 50 respectively) could be an area for improvement which could deliver enhancements in ecosystem service delivery (i.e. improved recreational experience, greater carbon sequestration etc).

k) To improve understanding of the trade-offs in the use of contested assets (e.g. between the use of ecosystem assets for recreation or biodiversity) and land use change (e.g. loss of ecosystems for built development). The information in the urban Melbourne EEA can be used to estimate what will be lost if the current ecosystems in the region are degraded / destroyed.

l) As a basis for collaborative working with land / water management organisations by using the accounts to explore synergies across ecosystems / geographic areas. This includes impacts and dependencies of assets under the Authority's management with other ecosystems / geographic areas. For example, the reliance of waterbody quality within urban Melbourne on land use outside of urban Melbourne area (and vice-versa).

m) As an underpinning evidence base to explore other policy and/or management issues including links to other reporting frameworks such as the Sustainable Development Goals, making the case for investing to expand ecosystem assets and estimating the magnitude and value of the loss of ecosystem service associated with pressures and risks.

n) As a useful contribution to the potential development of Victoria-wide environmental-environmental-economic accounts for urban areas.

5.4. Future of Urban Melbourne account

5.4.1. Refinement of Urban Melbourne account

This section outlines how this initial urban Melbourne EEA could be refined in the future, considering the extent, condition and physical / monetary flow accounts in turn.

Future refinement should also build on relevant work that has been published since the completion of the urban Melbourne EEA, including NCEconomics' 'Economic benefits of the Yarra River' (2018) – Released in February 2022.

5.4.1.1. Extent account

Estimates of the extent of the 9 broad ecosystems within the urban Melbourne EEA boundary are developed using existing land cover data from the Victorian Land Cover Time Series (VLCTS). The 19 VLCTS classes do not align directly with the 9 ecosystem types and so assumptions have been made to map the 19 VLCTS classes across to the 9 broad ecosystem types, with some reclassifications made as necessary to provide coherent / logical extent information. The resolution of the data is 25 metres, with each VLCTS class displaying one of the 19 land cover classes.

Future work could be undertaken to refine the land cover extent information, using more highly resolute datasets including (potentially) Earth Observation data for mapping street trees, road verges, beehives, green roofs/walls etc., potentially utilising the expertise and information that exists as part of the Digital Twin Victoria initiative (for example). This includes data on green roofs (to complement existing data) as well as green walls and facades being complied by the City of Melbourne. Consideration could also be given to the work being undertaken by Geoscience Australia (an Australian Government agency) with the Australian Government's Department of the Environment and Energy to develop national land cover datasets utilising the Food and Agriculture Organisation of the United Nations' Land Cover Classification System. The GeoScience Australia land cover dataset is not currently available for the urban Melbourne EEA, but this could be used in the future to align with work at Commonwealth level, thereby promoting a consistent approach to extent accounting in Australia.

5.4.1.2. Condition account

The condition account for this urban Melbourne EEA has been developed based on readily available information and is therefore does not comprehensively capture the ecological condition or socio-economic characteristics of ecosystem assets within the urban Melbourne EEA.

If environmental-economic accounts are developed over time, then changes in the metrics within the stock condition account can reveal changes in capacity of ecosystem assets in urban Melbourne region to provide ecosystem services. Further scientific and economic work should be done to explore "critical natural capital (ecosystem) asset characteristics" that are critical to supporting the provision of a specific ecosystem service of interest, such that if these characteristics were to decline, the capacity of urban Melbourne ecosystem assets to produce this ecosystem service declines substantially and (in some cases) abruptly and (potentially) irreversibly where threshold effects exist (Mace, 2019). This work should be done for each ecosystem service across the full range of ecosystem services typically provided by an ecosystem asset. Information / metrics on these critical characteristics are therefore crucial to include in the condition account and should be used to identify risk to socio-economic benefits (Mace et al, 2015). Continued declines in these "critical natural capital asset characteristics" suggests a degradation of the underlying stock of natural capital and the need for a policy or management response if risks to ecosystem service provision are to be avoided and the delivery of socio-economic benefits are to be sustained into the future.

5.4.1.3. Physical and monetary flow accounts

Opportunities for future refinement of the analytical approach to estimating the physical and monetary estimates for the assessed ecosystem services are as follows:

- **Air filtration:** The current approach just focuses on estimating air quality regulating service provided by trees. However, other green-blue infrastructure assets also capture pollutants and therefore further work could be undertaken to expand the scope of assets included within the account. In addition, the valuation of the air quality regulation service provided by trees in Melbourne does not include all of the pollutants that are estimated in the physical flow account as neither of the utilised studies valued PM10, CO or O_3 and so further work could be done to include a broader range of pollutants. Furthermore, some of the reviewed studies show that certain types of vegetation can result in increases in pollutant concentrations (by impeding the release to the atmosphere), such "ecosystem dis-services" are not covered within this account but could be considered in future work. Finally, consideration could be given to the availability of more refined methods to estimate the air quality regulating service of ecosystem assets, including those which calculate health benefits directly from the change in pollutant concentrations (i.e. exposure) rather than from tonnes of pollutant removed (see eftec et al, 2017).

- **Amenity:** Future consideration could be given to how amenity values vary according to a broader range of ecosystem asset types (beyond metropolitan parks and sports and recreation parks) and the quality of ecosystem assets (i.e. including the range of features that exist within parks including the diversity of flora and fauna) and park facilities (e.g. walking paths, bridleways, benches, toilets, playgrounds etc.) which contribute to determining people's enjoyment / welfare and physical and mental health benefits (for example, psychological studies by Lee (2015) and Lee et al (2014 and 2017) on the effect of green roofs on attention, cognitive function and productivity in Melbourne). Consideration could also be given to the amenity value that businesses (the current assessment estimates amenity value to residents only) place on accessible green-blue infrastructure, using a hedonic price methodology for commercial buildings as appropriate. The logic being that employees of businesses that are situated close to green-blue spaces benefit from the "bundle of ecosystem services" provided by these assets which delivers benefits to the business in terms of productivity, labour force satisfaction and retention, which in turn means that these businesses could be prepared to pay a premium for premises near green-blue infrastructure assets. Care would need to be taken not to double-count the amenity values estimated for residential premises. Information on the amenity value of urban ecosystems by socio-economic group could also be identified using available data such as that from .id community (.id community, n.d.).

- **Education**: The approach to measuring the physical provision of education from the ecosystems within urban Melbourne is based on the most comprehensive information available on educational visitation in Victoria and so no further refinement of the approach is recommended. The economic valuation is based on expenditures on educational activities which is assumed to provide a lower bound estimate of the value of outdoor education on common economic assumption that if benefits were not perceived to be greater than costs then the activity would not be undertaken in the first place. This valuation approach does not capture the true economic value of educational benefits associated with these trips (an area for potential future research) and so this presents an opportunity for future research to refine these estimates.

- **Biomass - food**: future work could seek to acquire / develop a comprehensive dataset on urban agricultural land use, yields and crop compositions, including for community gardens (Zainuddin & Mercer (2014) was only for domestic residential gardens). The study team contacted The Victorian Eco Innovation Lab at the University of Melbourne to request access to an urban agricultural dataset that was developed with the help of citizen scientists and gardeners as part of the project *"Urban agriculture's role in resilient city food systems"* (University of Melbourne, n.d.) but this was not released due to data sharing concerns. Furthermore, food production outside of commercial agriculture and community gardens could be estimated in the future, including from beehives, private gardens and (potentially) blue space (i.e. fishing). The role of urban pollinators (including bees), supporting urban crop production could be explored in the future including the trade-offs that exist between pollination by exotic European honeybees for urban honey production and access to pollen by native bees that do not produce honey but are critical pollinators supporting food production and biodiversity. Finally, there are a range of other potential socio-economic benefits of food production beyond the economic value of food production that could be included in future iterations of the account including reduced food miles, increased biodiversity, improved education and stronger community networks, improved health outcomes associated with fresher food and positive mental and physical wellbeing benefits associated with gardening as well as personal income being supplemented from selling surplus produce. Consideration could be given to the use of the bio-physical model InVEST (Integrated Valuation of Ecosystem Services and Trade-offs) to estimate (commercial) food production from urban ecosystems, see Box 5.1.

- **Global climate regulation**: Future refinement of the approach to estimating carbon <u>sequestration</u> from urban Melbourne ecosystem assets could expand the coverage of ecosystems beyond the two broad ecosystems (inland wetlands and forests) and two narrow ecosystem assets (trees and parks) that are currently assessed. The carbon <u>retention</u> service is estimated using the best data that is currently available on carbon stocks and so does not require any further refinement. The definition, measurement and valuation of carbon related services in environmental-economic accounting is a complex and developing area (Edens et al, 2019). Developments made through international and domestic deliberations on accounting for carbon sequestration and storage within environmental-economic accounts should be incorporated into future iterations of the urban Melbourne EEA. Consideration could be given to the use of the bio-physical models including iTree Street: STRATUM and InVEST (Integrated Valuation of Ecosystem Services and Trade-offs) to estimate the global climate regulating service from urban ecosystems, see Box 5.1.

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- **Local climate regulation**: The analysis of local climate regulation service in urban Melbourne for this EEA demonstrates how a simple modelling approach can be used to estimate the aggregate cooling effect of different categories of urban vegetation. The approach adopted for this urban Melbourne EEA is to estimate aggregate average cooling effects across the entire urban Melbourne EEA area. However, the cooling effect of urban green-blue infrastructure is likely to be highly context specific, influenced by urban form and the prevailing general and local climate. This ecosystem service is therefore extremely spatially dependent and so even if the aggregate effect of cooling by ecosystem assets is not estimated to be particularly large, it will be felt disproportionately at very localised levels. Therefore, the aggregate estimate of urban cooling across urban Melbourne that is produced in this EEA is a simplification of what is actually a spatially varied ecosystem service.

Notwithstanding the limitations of the broad approach, the specific studies used to estimate the cooling effect of urban ecosystem assets are highly uncertain. The estimates for parks are based on a Melbourne specific study that took place in autumn/winter when it might be expected that the temperature change due to parks might be different from spring/summer. The estimates for rivers are based on a UK specific study and its application to Melbourne is highly uncertain. Therefore, the estimates of the effect of Melbourne's urban parks and rivers on temperatures within Melbourne are both areas for future research.

In terms of the assessment of specific socio-economic benefits associated with urban cooling, the focus is on the avoided health and productivity costs of local climate regulation by urban ecosystem assets. The following are areas for refinement in this regard:

- The link between temperature and mortality is based on a dose-response function developed by AECOM (2012). However, this is a relatively simple approach that could be refined, such as by using information developed under the Victorian Heat Health Information Surveillance System developed by Nicholls et al (2008) (which was used by CRCWSC, 2019) and presented in Dept. of Health (2011). Consideration could also be given to key factors that might affect these dose-response functions since they were estimated, including changes in the prevalence of heat adaptation measures such as air conditioning and the thermal efficiency of buildings.

- The valuation of avoided healthcare costs relies on Medibank (2008) data, further work should be done to refine the evidence base used to value the avoided healthcare costs.

- The estimate of avoided productivity losses relies on an assumption adopted by CRCWSC (2019) that 20 per cent of jobs are affected by daytime heat. The actual application within this method is 20 per cent of economic output, which is different from jobs as certain jobs are more productive than others (i.e. output per worker varies across economic sectors). This is a crude approach as impacts on productivity will vary across economic sectors with those in air conditioned offices unlikely to be affected whereas the effects could be substantial where work requires strenuous outdoor activity (e.g. construction) with no air conditioning. Therefore, a more nuanced approach to identifying changes in economic output (GVA) by affected economic sectors could be developed. This could build on NCEconomics (2018) analysis of the cost to Victoria's economy (by sector and region) of heatwaves which estimates dose-response functions by economic sector. The key challenge in applying the NCEconomics (2018) estimates are that these are based on excess heat factor not ambient temperatures but could be used if the effect of urban ecosystem assets on excess heat factors can be established.

- The approach assumes that "hot day' impacts are additive (i.e. two sequential hot days have the same socio-economic impacts as two hot days separated by several months). Consideration could also be given to the possibility that sequential hot days may have greater socio-economic impacts.

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- In the future, consideration could be given to the quantification and valuation of wider socio-economic benefits that are associated with this ecosystem service as identified from the literature review including avoided energy costs, assaults, tree deaths, travel delays, tree irrigation, road and pavement maintenance, artificial shading and carbon emissions.

A refined approach to estimating this ecosystem service would be to develop locally specific estimates of urban cooling (local climate regulation) by *all* ecosystem assets in a locality. Similarly, localised estimates of the associated avoided socio-economic costs could be developed including for labour productivity according to localised economies as well as morbidity and mortality according to the socio-demographic composition of the local population across Melbourne. This could utilise information on historical peak daily temperatures from a range of weather stations within the urban area of the assessment boundary, not just from the Melbourne (Olympic Park) weather station. This would facilitate the development of a more disaggregated assessment of local climate regulation by urban ecosystem assets across urban Melbourne where changes in temperatures are based on local climate (temperatures, humidity, wind and radiation) as well as local urban form, local ecosystem asset extent and localised impacts on health outcomes and productivity. This would potentially be more useful from a policy perspective and also align better with the SEEA-EEA guidance which describes spatial accounts.

Consideration could be given to the use of the bio-physical models including InVEST (Integrated Valuation of Ecosystem Services and Trade-offs) to estimate the local climate regulating service from urban ecosystems, see Box 5.1.

- **Recreation**: The focus of the analysis is only on recreational visits to parks and piers that are Park Victoria assets and the Royal botanic gardens in Melbourne. Future work could be undertaken to estimate recreational visits to a broader range of urban ecosystem assets. This could be done as follows:

    a. Exploring the use of mobile phone data to quantitatively monitor visitation activity to specific urban ecosystem assets in a spatially explicit way across urban Melbourne. This would enable an understanding of spatial patterns of visitation over time including identification of hotspots of high use. This would require GPS coordinates for anonymised mobile phone triangulated positions within urban postcodes within Melbourne. Attribution with time and date would allow the analysis to be undertaken.
    b. Collecting information on specific ecosystem related recreation events. This could include estimating the recreational activity that takes place on privately owned green spaces including golf courses and sports fields (e.g. cricket / Australian-rules football ovals).

Future work could also estimate the number of nature-based recreational visits by different activity types, including the type and duration of physical activity (which is important for monetary valuation). Ideally this data on recreational visits/visitors to Melbourne's urban parks would be estimated on a spatially explicit basis (i.e. visits to specific ecosystem assets) as this would enable (a) clear selection of ecosystem assets and visits that fit within the boundary of this account and (b) the mapping of recreational value across Melbourne.

The approach to the monetary valuation of recreation is dependent on the estimation of recreational visits/visitors (i.e. if recreational visits are estimated by type of activity or not) but also on the economic valuation evidence that exists. The gaps in economic valuation evidence include the:

- The Read et al (1999) welfare value for recreation is over 20 years old and needs updating.
- Lack of information on the recreational value of water-based activity in urban settings in Victoria/Melbourne, with the BDA Group (2015) providing estimates for use in Victoria, based on studies undertaken in NSW and Queensland for waterway recreation ($40 per visit) and fishing ($60 per visit).
- Lack of a broad range of activity specific values in the literature, meaning that the valuation of physical activity type (if data existed) would rely on the application of estimates of value ($) for some activities (e.g. walking and cycling) as proxies for other activities;

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- Lack of Melbourne specific values for physical activities, meaning that valuation of physical activity types (if data existed) would rely on the application of values that were developed outside of Victoria / Melbourne (e.g. NSW and Queensland).

If estimates of community (and professional) engagement in sports on privately owned (and publicly owned) assets such as golf, Australian-rules football, cricket, soccer and boating can be identified then values for these activities can be included. Consideration could also be given to incorporating the value of these activities for spectators.

Whilst values on the avoided physical health costs associated with recreation have been obtained, there are no such values for use on the mental health benefits of outdoor recreation which are expected to be substantial (Griffith University, 2020). Further work could explore if / how to capture the mental health benefits from single or regular visits to urban green and blue space (link to food provision from private and community gardens which provides mental health benefits in addition to the actual provision of food) in a way that ensures no double counting of value.

Consideration could also be given to incorporating information on visitor satisfaction (e.g. from Parks Victoria on an index of 1 to 100) into economic valuation estimates of recreation visitation to the urban Melbourne EEA region, on the basis that visitors place higher value on visits that provide greater satisfaction. Similarly, any documentation of a visual record of place as "experienced on the ground" could be incorporated into the account to understand and assess the unique place qualities (pers. comm. Marie Clare O'Hare, DJPR).

The current approach focuses on the value of recreation as an input to consumption by individuals (health and wellbeing benefits) and does not consider the contribution to production by economic sectors (recreation and tourism expenditures). These values are predominantly non-SNA values (there is technically some support of production through improved labour productivity as a result of recreational consumption by individuals), which means that the values that are not currently captured in the System of National Accounts. Future work could consider how to include the urban ecosystems' contribution to the economy through its support of Gross Value-Added (GVA) in the recreation and tourism industry (i.e. estimating the reliance of GVA within a region on the natural environment) (existing studies of relevance include MJA (2016), Maller et al. (2002) and Deloitte (2014))

Consideration could be given to the use of the bio-physical models including InVEST (Integrated Valuation of Ecosystem Services and Trade-offs) to estimate recreation as an ecosystem service from urban ecosystems, see Box 5.1.

Box 5.1. The InVEST (Integrated Valuation of Ecosystem Services and Trade-offs) Tool

InVEST is a suite of free, open-source software models that can be used to map and value the goods and services from nature that sustain and fulfill human life. InVEST models are spatially-explicit, using maps as information sources and producing maps as outputs. InVEST outputs are either in biophysical terms (e.g. tonnes of carbon sequestered) or economic terms (e.g. value of carbon sequestered).

The draft guidance on biophysical modelling for SEEA-EEA (Tomscha, 2019) outlines a tiered approach to developing accounts with approaches such as InVEST that rely on globally available datasets and pre-constructed ecosystem service models using freely available tools, requiring very little user input, being classified as Tier 1 approaches (See Annex 8 for further detail).

Many of the methods adopted to quantify (and value) ecosystem service provision in the reviewed literature are bespoke based on the data and methods available within each country/region (these are classified by Tomscha (2019) as Tier 3 approaches), although some of the reviewed studies adopt the publicly available biophysical models such as iTree (Tier 2 which use national datasets, requiring some customisation and validation of ecosystem service models) and InVEST (Tier 1).

A Tier 3 approach to developing a SEEA-EEA is ideal for accuracy, however, rough estimates based on global models and global datasets are a first step towards locally parametrised models, and many organisations may choose to initiate SEEA-EEA using a Tier 1 approach (Tomscha, 2019).

The potential advantage of using bio-physical models such as InVEST is that they can promote a consistent approach to assessing ecosystem services globally, although the predictive value and robustness of these models has to be weighed up against the use of customised approaches using local data on production and context specific assumptions. The Natural Capital Project (n.d.) explain the approach used by InVEST to quantify the value of ecosystem services assessed in this initial Melbourne EEA as follows:

- **Biomass - Food (commercial):** *"The Crop Production Percentile and Crop Production Regression models estimate crop yield and nutrient value for a fixed set of crops, derived from user-supplied landcover information. Crop yield is primarily driven by climate and fertilizer rates."*

- **Global climate regulation***: "The InVEST Carbon Storage and Sequestration model estimates the current amount of carbon stored in a landscape and values the amount of sequestered carbon over time. First it aggregates the biophysical amount of carbon stored in four carbon pools (aboveground living biomass, below ground living biomass, soil, and dead organic matter) based on land use/land cover (LULC) maps provided by users. If the user provides a future LULC map, the carbon sequestration component of the model estimates expected change in carbon stocks over time…The carbon model can also optionally perform scenario analysis according to the Reducing Emissions from Forest Degradation and Deforestation (REDD) and REDD+ frameworks…The model values the amount of carbon sequestered as an environmental service using additional data on the market value or social cost of carbon, its annual rate of change, and a discount rate."*

- **Local climate regulation**: "*The InVEST urban cooling model calculates an index of heat mitigation based on shade, evapotranspiration, and albedo, as well as distance from cooling islands (e.g. parks)."*

- **Recreation:** *"The InVEST recreation model predicts the spread of person-days of recreation, based on the locations of natural habitats and other features that factor into people's decisions about where to recreate. In the absence of empirical data on visitation, we parameterize the model using a proxy for visitation: geotagged photographs posted to the website flickr. Using photographs, the model predicts how future changes to natural features will alter visitation rates and outputs maps showing current and future patterns of recreational use."*

- **Cross-cutting areas** for refinement associated with monetary valuation include:

- **Validity of stated preference (e.g. willingness-to-pay) based survey estimates**: in many cases the ecosystem services that are provided by ecosystem assets are enjoyed for free to society at the point of use. For example, the entrance to a local park is free. In this case, market data suggests the park has no economic value. However, in reality park users derive benefit from using or viewing the park and so the economic value is potentially significant. This example demonstrates the difference between economic value and financial value. The economic (or "welfare") value of ecosystem services can be measured by carefully designing stated preference surveys to estimate individual willingness to pay for the service and aggregating these values over the beneficiary population. The design of these surveys and studies is critical to their validity and further work should be done to build the evidence base on the value of urban ecosystem services in Melbourne where stated preference methods have been adopted.

- **Contribution of other inputs**: For the purpose of this initial account, the contribution of other economic inputs to the value of ecosystem services produced from Melbourne's urban ecosystems is only partially estimated (for market goods and services only) and is therefore an overestimate. In the future a more comprehensive estimate of resource rent could be made by developing an "expenditure account" which reports the cost of managing urban ecosystem assets (e.g. pruning street trees, planting flower beds, cutting park grass).

5.4.2. Expansion of Urban Melbourne account

In terms of expansion of the urban Melbourne EEA, not all of the eleven ecosystem services that were identified as being potentially within scope of this initial urban Melbourne assessment were assessed. The following ecosystem services were scoped out for consideration under this initial EEA but could be incorporated in the future:

- Flood mitigation
- Noise regulation
- Research
- Water purification
- Water supply
- *(Smell regulation - not identified in initial eleven ecosystem services but noted by steering group)*

The three water based ecosystem services (flood risk regulation, water quality regulation and water provision) were scoped out for this urban Melbourne EEA because existing Melbourne specific data / analysis did not exist to enable quantification and valuation of these services within the study area. To quantity and value these services requires more advanced techniques (e.g. technical bio-physical modelling), some of which exist within DELWP and/or would require further research / analysis. This could be a key area for future expansion of the accounts.

Whilst water provision has been estimated in some studies as a provisioning service on the basis that ecosystems retain water within a catchment (prior to flowing to sea), the UN (2019) notes that water is not the result of ecosystem processes and therefore water supply may be better categorised as an abiotic (rather than a biotic) ecosystem service. The study team suggests that further work is needed to be done to understand the ecosystem service associated with water provision and how it is to be assessed in environmental-economic accounts from a practical perspective.

Another key area for expansion could be research in the natural environment which is often considered alongside education in environmental-economic assessments, with the physical provision of research being measured through the number of scientific research projects (e.g. research permits issued). This has not been considered within this urban Melbourne EEA as the benefits of research are deemed to be sufficiently different to that of education for it to warrant its own assessment in the future. The benefits of research into the natural environment include productivity or efficiency gains in the management of native species, improved technology and new medicinal products through research into genetic material. In theory, the value of such research can be measured through the impact on socio-economic outcomes. However, in practice, that value will depend greatly on the research outcomes sought as well as the adoption and long-term impact of research outcomes in society. Further work into the specific use of the ecosystems within the urban Melbourne EEA region for environmental research could be undertaken to establish whether this value is likely to be substantial. This should utilise the work done by Sommerville (2020) for Parks Victoria on the value of research in Victoria's parks and reserves.

5.4.3. Potential future use of the Urban Melbourne account

In the future, the information in accounts can also be used in conjunction with other information to support decision making and reporting regarding ecosystem assets in the region, in particular:

a) Applying historical data to the framework that has been developed for urban Melbourne EEA to enable changes in ecosystem status and productivity to be understood over time by comparing with the urban Melbourne for 2019. The "historical" period(s) adopted will depend primarily on data available.

b) Applying projections of key variables (population, climate change etc.) to estimate the future magnitude and value of ecosystem services into the future as a capitalised value of ecosystem stocks (like the value of a house), rather than the annual value at a point in time (like the rent paid on a rental property) which can be useful in demonstrating the value of ecosystems over the long term. Asset values are estimated through the present value ($) of expected future flows of ecosystem services accounting for expected variations in both the physical and monetary flow due to population growth, climate change and other relevant variables over a relevant time period. Defra and ONS (2017) define the relevant time period as the time over which ecosystem services are expected to be supplied by an ecosystem asset.[62]

c) Consider integration of the urban Melbourne EEA information with other information to report on the Sustainable Development Goals (SDGs) which are a collection of 17 interlinked global goals designed to be a "blueprint to achieve a better and more sustainable future for all" (UN, n.d.). The SDGs identify specific targets for each goal, along with indicators that are used to measure progress towards each target. UN SEEA framework is a systematic approach to environmental-economic accounting which makes it useful for directly measuring several SDG indicators. Progress towards the 17 SDG goals are monitored through 244 indicators. Urban environmental-economic accounts provide information that is relevant for reporting on Sustainable Development Goals particularly SDG 11: Sustainable Cities and Communities as identified in SEEA Revision guidance (UN, 2020) as outlined in Table 5.4.1.

Table 5.4.1. Links between urban environmental-economic accounts and the Sustainable Development Goals (UN, 2020)

SDG Number	Description
11.3.1	Ratio of land consumption rate to population growth rate
11.4.1	Total expenditure (public and private) per capita spent on the preservation, protection and conservation of all cultural and natural heritage, by type of heritage (cultural, natural, mixed and World Heritage Centre designation), level of government (national, regional and local/municipal), type of expenditure (operating expenditure/investment) and type of private funding (donations in kind, private non-profit sector and sponsorship
11.6.2	Annual mean levels of fine particulate matter (e.g., PM2.5 and PM10) in cities (population weighted)
11.7	By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities.
11.7.1	Average share of the built up area of cities that is open space for public use for all, by sex, age and persons with disabilities
11.7.1 (modified)	Average share of the built up area of cities that is Blue Green space for public use for all, by income distribution, by sub-municipal area
15.3.1	Proportion of land that is degraded over total land area

[62] UK urban accounts (eftec, 2017) adopt a 100-year asset life to reflect that ecosystem service flows can be supplied indefinitely if these assets are managed sustainably (UN et al., 2012) and a 100-year period captures ~92 per cent of the net present value of continued flows into perpetuity (using HMT discount rates) (Defra and ONS, 2017).

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Additional examples (i.e. not set out in SEEA (2020)) of where environmental-economic accounts can provide information of relevance to the SDG indicators are outlined in Table 5.4.2. These links could be relevant to an urban account depending on the assessment boundary and the specific ecosystems that exist within an urban setting.

Table 5.4.2. Additional links between urban environmental-economic accounts and the Sustainable Development Goals

SDG Goal	SDG indicator example	Potentially relevant SEEA-EA account	
		Extent account	Condition account
2. Zero Hunger	2.4.1. Proportion of agricultural area that is productive and sustainable	●	●
6. Clean Water and Sanitation	6.3.2. Proportion of bodies of water with good ambient water quality		●
	6.6.1. Change in the extent of water-related ecosystems over time	●	
14. Life Below Water	14.1.1. Index of coastal eutrophication and floating plastic debris density		●
	14.3.1. Average marine acidity (pH) at representative sampling stations		●
	14.4.1. Proportion of fish stocks within biologically sustainable levels		●
	14.5.1. Coverage of protected areas in relation to marine areas		●
15. Life on Land	15.1.1. Forest area as a proportion of total land area	●	
	15.1.2. Proportion of important sites for biodiversity that are protected areas		●
	15.4.1. Coverage of important sites for mountain biodiversity that are protected		●
	15.4.2 Mountain Green Cover Index		●
	15.5.1 Red List Index		●

d) To build the business case for investment to expand ecosystem assets within the urban Melbourne EEA region. The underlying data and analysis that is used to build the urban Melbourne EEA could be applied to estimate the physical and monetary value of prospective changes in ecosystem extent that might be delivered through future policy/management/investment. An example of how the Melbourne EEA information has already been used as a basis for policy analysis within DELWP is set out in Annex 15. The analysis in Annex 15 estimates the economic value of enhanced green infrastructure (tree cover and vegetation) in Melbourne in 2051 that could be delivered through amendments to Victoria's planning policy. The analysis was developed by the DELWP economics team using the information on local climate regulation that has been compiled in the environmental-economic account for Melbourne.

e) To assess the magnitude and value of the potential future loss of ecosystem service associated with pressures and risks in the urban Melbourne EEA region. Many of the changes to the natural environment are the deliberate (e.g. urban development) or inadvertent result of human use of ecosystem services (e.g. pollution assimilation by water bodies). These pressures can occur in parts of the catchment that are a significant distance from the urban area where the effects are felt. Quantifying the cause and effect relationships between prospective human activities and the impact on ecosystem services, particularly where the effects of the activity are separated from the activity in space and/or time is a key challenge in adopting a sustainable approach to decision-making for the Victorian environment.

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Traditional decision making frameworks have been unable to encompass such interactions (e.g. across a catchment), nor have they allowed for a full assessment of the trade-offs that are sometimes inherent in the use of the natural environment for human benefit. As a result, the value of ecosystem services that is being traded off in pursuit of commercial gain is not captured and decisions are made on partial information about costs and benefit to society. Non-market valuation methods can be used to estimate the economic value ($) of non-commercial activities. By quantifying the value of all of the ecosystem services that are at risk of being lost, comprehensive trade-off decisions can be taken on the basis of full information about *all* economic values, not just those associated with commercial interests (Worley Parsons, 2013).

A qualitative / descriptive “sustainability assessment” (see Arena et al, 2015) could be a simple way to summarise pressures on the status and productivity of ecosystem assets within the urban Melbourne EEA area. Alternatively, the DPSIR framework (see Waite et al, 2014) provides a systematic and internationally accepted framework to assess pressures on ecosystem asset status (ecosystems, habitats and species) and changes in productivity (i.e. provision of socio-economic benefits).

The Drivers, Pressure, State, Impact, Response (DPSIR) framework has been used by the European Environment Agency and the United States Environmental Protection Agency amongst others (Waite et al, 2014) to describe the multiple causal biophysical links between pressures and impacts on ecosystems. The DPSIR framework is a complementary framework to environmental-economic accounts insofar as it assess pressures (e.g. invasive species) on the status of an ecosystem asset stock and the associated change in ecosystem service flows (DELWP, 2016).

The DPSIR framework is best suited to situations where there are clear and distinct drivers of change that need to be considered, such as increased tourism (Waite et al, 2014). The DPSIR approach allows stakeholders to think through how drivers and pressures cause changes in the natural environment, what the change in the state of the natural environment is and the potential impacts of this, and what responses (such as a policy change) could reduce or eliminate the impacts or improve ecosystem condition.

A list of data and evidence to inform the scope of pressures that could be included in a future assessment in conjunction with the data in the urban Melbourne EEA is set out in Table 5.4.3.

Table 5.4.3. Pressures on Melbourne’s urban ecosystems - non-exhaustive list of potential metrics and sources

Data description	Metric	Geographic Scope	Source	Year
Population change	No.	Melbourne	DELWP (2019) Victoria in Future report	Future
Sea-level rise	cm	Port Phillip Bay	Bureau of Meteorology	1970-20
Tree removal	No.	City of Melbourne	Uni. Of Melbourne et al (2020) Patterns of tree removal and canopy…	2008-17
Temperature change	°C	Melbourne	CSIRO (2016) Climate change in Australia	Future
Urban development / Greenfield loss	Various	Melbourne	DELWP (2019) Urban Development Program	Future
Wildfire	Ha	Victoria	DELWP (2020) fire	1903-2020
	Classification	Victoria	DELWP (2020) fire intensity	2000-2020

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Annex 1. Scoping phase approach

The project commenced through the following sub-tasks that were completed in parallel:

a) **Review economic assessments of urban ecosystem assets globally**: consider the breadth of approaches, principles and concepts as well as the type of data and evidence that is used in existing economic assessments of urban ecosystem assets. The review focused on economic assessments of the natural environment that use the environmental-accounting framework (i.e. asset stocks and ecosystem service flows) in order to remain manageable. The geographic location of the assessments reviewed are as follows, further details of the specific studies are provided in Table A1.:

- Lower Fraser Valley (Vancouver), Canada
- Ontario, Canada
- National Capital Region, Canada
- Leipzig-Halle region, Germany
- Oslo, Norway
- Wellington, New Zealand
- UK
- London, UK
- Birmingham, UK
- Manchester, UK
- Northern Ireland, UK
- Utrecht, Netherlands
- USA
- Lancaster, Pennsylvania, USA
- North Carolina, USA

b) **Review international guidance on environmental-economic accounting:** consider the international best practice guidance on environmental-economic accounting including that specifically related to urban ecosystems. This includes (but is not limited to) the UN System of Environmental-Economic Accounting – Environmental-economic accounts (SEEA-EA) technical guidance and discussion papers and relevant non-accounting specific literature such as the UK Government guidance on Enabling a Natural Capital Approach, the European Environment Agency's Common International Classification of Ecosystem Services (CICES) and publications by the European Commission's Mapping and Assessment of Ecosystems and their Services (MAES) as well as the Intergovernmental Panel on Biodiversity and Ecosystem Services (IPBES).

The above tasks were used, along with project team experience in developing environmental-economic accounts, to form a framework for the urban Melbourne EEA that is consistent with global best practice, setting out the *potential* scope of the account. The following tasks then *established* the scope of the account (i.e. mapping the detail against the framework) based on the specific Melbourne context given the data and methods available. Taken together, these tasks were important in establishing data and evidence gaps that could be filled in the future to expand and/or refine the urban Melbourne environmental-economic account.

c) **Review existing information on the urban ecosystems within Melbourne:** undertake a review of existing data and methods used in existing economics assessments of urban ecosystems in Victoria/Australia, utilise project team knowledge of existing data and methods and consult with DELWP colleagues to identify and review existing data, evidence and analysis on the urban ecosystems within Melbourne that could be useful for developing an environmental-economic account.

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Table A1. Reviewed economic assessments of green-blue infrastructure globally

Country	Title
UK	eftec (2017) A study to scope and develop urban natural capital accounts for the UK
UK (London)	City of London (2011) City of London Green Roof Case Studies
UK (London)	eftec (2015) Beam Parklands Natural Capital Account
UK (London)	GLA (2015) Natural Capital Investing in a Green Infrastructure for a Future London
UK (London)	eftec (2016) London Borough of Havering Green Infrastructure Strategy
UK (London)	GLA (2016) The Mayor's street tree initiative
UK (London)	GLA (2016) Economic Evidence Base for London 2016
UK (London)	kMatrix (2013) London's Low Carbon Market Snapshot – 2013
UK (London)	JSA and eftec (2016) London Borough of Barnet Corporate Natural Capital Account
UK (London)	Treeconomics (2015) Valuing London's Urban Forest. Results of the London i-Tree Eco Project
UK (Manchester)	eftec (2018) Natural Capital Account for Greater Manchester
UK (Manchester)	Defra & GMCA (2016) The Defra urban natural capital pioneer
UK (Manchester)	BDP et al (2015) Manchester Green Infrastructure Strategy Technical Report
UK (Birmingham)	Birmingham City Council (2013) Green Living Spaces Plan
UK (Birmingham)	RICS (2015) Planning for Sustainable Land-Use: The Natural Capital Planning Tool (NCPT)
UK (Birmingham)	Hölzinger, O. (2011) The Value of Green Infrastructure in Birmingham and the Black Country
UK (Birmingham)	Hölzinger, O. (2015) Birmingham & The Black Country Nature Improvement Area Ecosystem Assessment.
Northern Ireland (Belfast)	Natural Capital Solutions (2018) Natural Capital Assessment in Northern Ireland: Urban Study
Norway (Oslo)	Barton et al (2015) The international OpenNESS project's Oslo case study
Norway (Oslo)	EC (2016) The EU MAES project on urban ecosystems: Oslo case study
Netherlands (Utrecht)	Natural Capital Solutions (2018) Natural Capital Assessment in Northern Ireland: Urban Study
Germany (Leipzig-Halle)	Barton et al (2015) The international OpenNESS project's Oslo case study
NZ (Wellington)	EC (2016) The EU MAES project on urban ecosystems: Oslo case study
US	Heris et al (2021) Piloting urban environmental-economic accounting for the United States
USA (Pennsylvania)	EPA (2014) The economic benefits of green infrastructure, a case study of Lancaster, PA
USA (Pennsylvania)	City of Lancaster (2011) Green Infrastructure Plan
USA (North Carolina)	The Trust for Public Land (2010) The economic benefits of the park and recreation system of Mecklenburg Country, North Carolina
Canada (Vancouver)	Ducks Unlimited Canada and the Nature Conservancy of Canada (2004) The value of natural capital in settled areas of Canada
Canada (National Capital)	National Capital Commission (2016) Natural capital - The economic value of the national capital commission's green network
Canada (Ontario)	Green Analytics (2016) Ontario's Good Fortune: Appreciating the Greenbelt's Natural Capital

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Annex 2. Defining the assessment boundary

This section summarises how the boundary of urban environmental-economic accounts are defined in the reviewed assessments and guidance (see Annex 1) and outlines the approach for the urban Melbourne EEA.

A2.1. Review of boundary definition in global assessments of urban ecosystems

The geographic boundary of the assessment or the "environmental-economic accounting area" sets the land area within which the status and productivity of ecosystem assets will be estimated and reported. Within this boundary there may be many different ecosystem types, of which the urban ecosystem may be one. Therefore, the geographic boundary does not (necessarily) define the urban area to be assessed, but rather defines the boundary of the land area to be assessed.

SEEA discussions (pers. comm. London Group on Environmental Accounting, 2019) indicate defining the boundary for urban accounts should be flexible and country-specific, based on policy needs and data availability. However, it is also acknowledged that a harmonised approach would improve comparability between countries and support other reporting efforts (e.g. reporting on the Sustainable Development Goals). Based on the reviewed literature, the geographic accounting area for urban EEA is typically based on:

a) **Administrative boundaries**: such as local government areas. For example, urban accounts have been developed in the UK for the London Borough of Barnet and for the combined authorities of Greater Manchester and Greater London. Most of the cases reviewed use administrative boundaries as the geographic area for the urban EEA and (implicitly or explicitly) assume that all ecosystem assets within that boundary are "urban ecosystems". The advantage of using administrative boundaries is that policy and planning decisions are often relevant to these boundaries and statistics are often readily available for these areas. There was however variation in the boundary used, both within and across countries (see Table A2.1.), reflecting:

- Different naming conventions across countries for the same type of boundary; and
- Different levels of administrative governance within and across countries.

Table A2.1. Administrative boundary examples

Administrative boundary	Example	
City councils	- Wellington City Council, New Zealand	- City of Lancaster, USA
Municipalities	- Oslo, Norway - US national account	- Utrecht, Netherlands
Boroughs	- Birmingham and the Black Country, UK	- London Borough of Barnet, UK
Combined authorities	- Greater London, UK	- Greater Manchester, UK
Regions	- Lower Fraser Valley, Canada - National Capital Region, Canada	- Leipzig-Halle, Germany
Counties	- Mecklenburg County, USA	

b) **Functional boundaries**: including spatial planning regions (i.e. urban growth boundaries) and commuting zones. The Ontario, Canada study assesses the 'Ontario Greenbelt' which is an urban growth boundary established to protect prime farmland and environmentally sensitive areas from urban development and sprawl. Whilst this Canadian assessment focuses on the greenbelt area rather than the urban area it encapsulates, Melbourne's urban growth boundary represents an alternative assessment boundary. The OECD Functional Urban Areas is based on commuting zones around metropolitan areas and could provide a consistent approach to defining urban areas globally.

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c) National boundaries: Based on the literature reviewed, the US (Heris et al, 2021) and the UK are the only countries to have developed an urban environmental-economic account at national level (eftec, 2017). The UK has done so as part of a suite of comprehensive (covering entire land area) and mutually exclusive (a given land area is only included once) EEA for the country. As part of this UK urban EEA, an approach to defining urban ecosystems across the entire land area was devised (based on built-up areas). The US study (Heris et al, 2021) uses municipal boundaries (see Table 1) with a population of 50,000 or more, recognising that this definition excludes sub-urban, and exurban areas which is justified on the basis that these areas provide ecosystem services of lower value than denser core urban areas. For the purpose of developing comprehensive and integrated accounts at national level, administrative and functional boundaries are not appropriate to use to define urban ecosystems because these boundaries would not capture *all* urban areas across the country. As such, administrative and functional boundaries are more appropriate boundaries for EEA for large metropolitan areas that are developed in isolation (i.e. not as part of a suite of comprehensive and mutually exclusive EEA at regional / state / national level).

A.2.2. Potential geographic boundaries for urban Melbourne EEA

The following options for defining the geographic boundary of the urban Melbourne EEA were identified based on a review of available spatial boundary datasets for the Melbourne area, Figure A2.1. shows the geographic extent of these boundaries and Table A2.2. sets out the pros and cons of each option:

- **Greater Capital City Statistical Area (GCCSA)**: GCCSAs form part of the Australian Bureau of Statistics (ABS) Australian Statistical Geography Standard (ASGS) and are designed to represent the functional extent of each of the eight state and territory capital cities. (ABS, 2016);

- **OECD Functional Urban Area:** Using population density and travel-to-work flows as key information, a functional urban area consists of a densely inhabited city and of a surrounding area (commuting zone) whose labour market is highly integrated with the city (OECD, 2013). The OECD outer core Functional Urban Area boundary is identical to the GCSSA boundary;

- **Urban growth boundary for Melbourne:** indicates the long-term limits of urban development and where non-urban values and land uses should prevail in metropolitan Melbourne (Victorian Government, 2017);

- **Melbourne Metropolitan Region:** this is the declared Melbourne metropolitan area, also known as Greater Melbourne, which consists of 32 Local Government Areas (Victorian Government, 2017);

Figure A2.1. Geographic extent of Melbourne by different boundaries

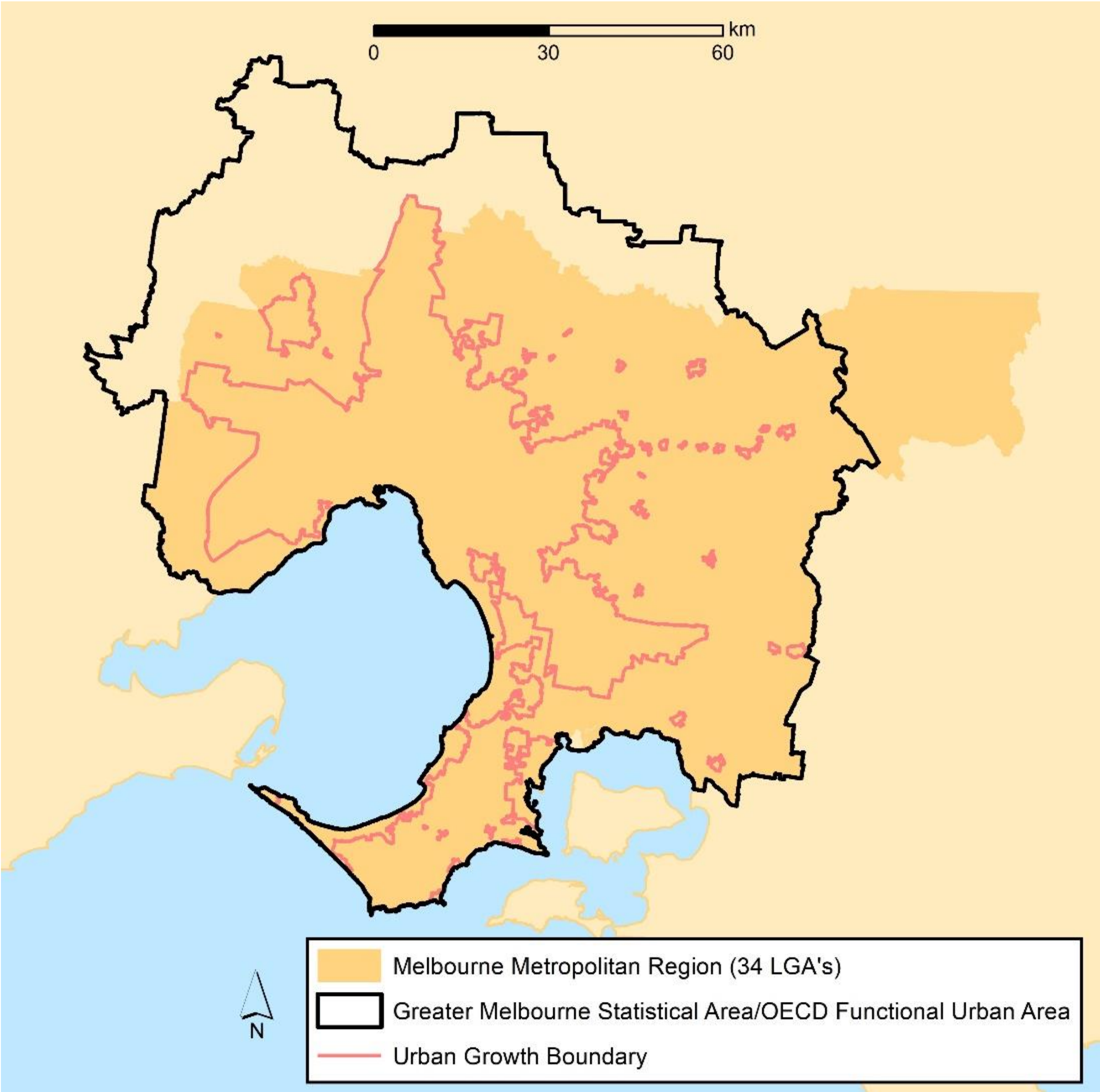

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Table A2.2. Pros and cons of different geographic boundary options

Boundary	Pros	Cons
OECD Functional Urban Area & Greater Capital City Statistical Area	- Potentially useful for international comparison as it was identified in UN SEEA Revision documents (UN, 2019) as a potential dataset to use to create more comparable spatial units for urban areas globally. - Greater Capital City Statistical Area offers consistent urban extent for comparison to other Australian cities and correlates with ABS statistical areas. - Correlates with 2014 and 2018 Melbourne vegetation cover mapping extent.	- Potential to change over time as it is based on population density and the city's commuting zone. - Unclear if this is being adopted for international comparison. - Potentially less useful for informing policy than an administrative boundary (for which policy is formulated).
Urban growth boundary	- Sets the legal boundary for urban growth within Melbourne so an account would show urbanisation over time within Melbourne.	- Potentially less useful for informing policy than an administrative boundary (for which policy is formulated). - Is subject to change with updates to planning strategy.
Melbourne Metropolitan Region	- Used by DELWP Planning to inform planning policy decisions for Melbourne. - Based on LGAs, so links to ABS datasets. - Provides a collaborative opportunity with LGAs. - Incorporates the entire urban growth boundary and OECD core functional area and much of the OECD outer functional area. - Unlikely to change in the future, thereby facilitating comparison of accounts over time. - Correlates with regional city LGAs. - Correlates with VPA & VEAC open space study areas.	- Is not an internationally consistent approach to defining assessment boundaries for urban areas so does not facilitate international comparison. - Is not a nationally consistent approach to defining capital city areas.

The scope of the assets to be included within the urban assessment for Melbourne are those that are actually situated within the urban fabric. The study is therefore interested in the contribution of assets *located in* urban areas to society's consumption of ecosystem services and benefits (i.e. including people who are situated within and (potentially) outside of urban areas). This is not to be confused with a possible alternative approach that includes *all* assets that deliver ecosystem services / benefits to the urban population. The study will also therefore not capture the relative contribution of urban ecosystem assets to Melbourne residents' use of ecosystem services (as the total use of ecosystem services is needed to get this result). Some examples of (non-urban) environmental assets far outside of urban areas that contribute to the *production* of ecosystem services that are *consumed* (in part or totally) by beneficiaries within an urban (built-up) area include:

- Water quality in urban areas can be affected by filtering of sediments and pollutants (i.e. water quality regulation) far upstream in a catchment (in a non-urban area);
- Air quality in urban areas can be affected by pollutant capture by / deposition on environmental assets (i.e. air quality regulation) that are located far outside of urban areas, but benefit people inside urban areas (assuming

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the alternative of no vegetation/blue space would mean pollution travelling into the urban area);

- Aesthetic views of landscapes and seascapes that are far outside of the urban boundary are often enjoyed by people in urban areas (the extent to which this transboundary effect could be being picked up in the assessment will depend on the scope and approach to defining urban ecosystem assets and estimating ecosystem services e.g. aesthetic views that are valued using hedonic pricing could capture transboundary effects. This will be noted in the final methodology report for Phase one of this project).

If the approach were to include all assets that contribute to the consumption of ecosystem services in urban areas, (as opposed to the proposed production of ecosystem services from assets located in urban areas), then the relevant boundary of the assessment would need to be determined on a case by case basis for each ecosystem service, according to the geographic scope of assets that contribute to the consumption of that ecosystem service within the urban area of interest (e.g. a catchment scale for water quality in urban areas located near the mouth of a river). Under this alternative approach, environmental assets that are situated in urban and non-urban areas would be included in the assessment.

Furthermore, the study will not consider the “import” and “export” of ecosystem services across the geographic boundary of the account. For example, food produced within Melbourne (which will be captured within the account) might not be consumed within Melbourne, but “exported” and consumed elsewhere. Similarly, food consumption by Melburnians will embody ecosystem services that have been “imported” following production elsewhere (which will not be captured within the account).

Further work needs to be done on how environmental-economic accounts should acknowledge the interactions across ecosystems / accounting boundaries that mean the ecosystem service consumed in a specific area may have been produced as a result of the combined contributions of multiple assets’ ecological functioning across space and time. Evidence on such interactions could be useful from a planning perspective to understand the impacts and dependencies of a specific city / region on ecosystem assets beyond that city / region. This consumption based / ecosystem service approach to determining the geographic boundary of the account is not proposed for the Melbourne EEA because it is not as conducive to developing a set of integrated, mutually exclusive accounts for Victoria as a production based / ecosystem asset account. This is consistent with the UK government’s approach to developing a set of integrated ecosystem (natural capital) accounts.

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Annex 3. Defining urban ecosystem assets

A.3.1. Review of global assessments and guidance

Urban ecosystems are one of nine broad ecosystem types that are proposed as a classification for the purposes of developing environmental-economic accounts within Victoria, see Box A3.1.

Box A3.1. Classifying and mapping ecosystem assets for environmental-economic accounting Victoria

SEEA does not provide a classification of ecosystems/land covers (Bordt, 2019). Whilst is it understood that the SEEA Revision process is considering the IUCN Global Ecosystem Typology (GET)[63] as a "reference classification" to use in the absence of a national classification of ecosystems (UN, 2019), this is yet to be confirmed. The study team will keep abreast of developments in the SEEA Revision process and ensure that the ecosystem classification adopted in the urban Melbourne EEA is sufficiently broad to align with the IUCN GET should it be established as a reference classification by SEEA.

Geoscience Australia (an Australian Government agency) has been working with the Australian Government's Department of the Environment and Energy to develop national land cover datasets utilising the Food and Agriculture Organisation of the United Nations' Land Cover Classification System. The GeoScience Australia land cover dataset is not currently available for the Melbourne EEA, but the study team will continue to keep abreast of developments in this initiative to see if / how the Melbourne EEA can align with and potentially make use of the proposed classification as appropriate.

The proposed classification of ecosystem assets for Victoria (including urban ecosystems) has been developed to meet **all** the following criteria:

- **Comprehensive**: the classification of ecosystem assets must cover all ecosystems across the entire land area so that any changes in land cover are reflected within an account. This requires the boundaries of the ecosystems for which accounts will be developed to be defined and classified and then practically developed in GIS. Examples of "ecological system" boundaries that are used to develop a set of mutually exclusive accounts are "habitats" which are used to define the boundaries of UK national environmental-economic accounts (the UK is to develop a suite of environmental-economic accounts for 8 broad habitats) including urban habitat. In practice a land cover map is used and aligned to these broad habitats (Defra and ONS, 2017). From an urban ecosystem perspective, the classification of urban ecosystems must include both the built environment and ecosystem assets that are embedded within the urban fabric (e.g. parks, street trees etc).

- **Mutually exclusive**: a given land area must only be classified (and accounts practically developed in GIS) as one type of ecosystem asset in order to avoid double counting of land areas and overestimating the value of ecosystems. This criterion (along with the classification being comprehensive) facilitates the development of a set of environmental-economic accounts for Victoria, should this be desirable in the future. This criterion means that increases in the urban ecosystem extent due to urbanisation will be offset by losses in other ecosystem extent accounts (e.g. grassland, forests etc.).

[63] The International Union for Conservation of Nature (IUCN) are developing a standardised, globally consistent and spatially explicit typology and terminology for managing the world's ecosystems and their services.

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- **Links to physical provision of ecosystem services:** the classification of assets must provide clear and logical links to differences in the physical provision of ecosystem services. In doing so it will facilitate an understanding of the capacity of a geographic area to support human health and wellbeing. Without this link to service provision, the accounts do not provide any additional insight to other reports that compile information on ecosystem extent (which are largely reporting from an ecological / biodiversity perspective).

- **Links to monetary value of ecosystem services:** the classification of assets must reflect the proximity of ecosystems assets to beneficiaries as being a key determinant of socio-economic value. This will require the classification to distinguish between the same ecosystem asset type within an "urban" and "non-urban" location. For example, separating "grassland" as a broad ecosystem from "urban grassland" and "highly managed assets" in urban areas, including parks. These distinctions between what might appear to be very similar assets in form (i.e. they could all be considered as "grassland"), is necessary because the level and value of ecosystem service provision across these assets could vary substantially due to the:

  a) Close proximity of urban residents (beneficiaries) to "urban" natural capital assets means that the value of these assets is likely to be proportionately greater than equivalent "non-urban" natural capital assets;
  b) High degree to which "urban" natural capital assets (e.g. parks, street trees) are managed to deliver the desired socio-economic benefits compared to "non-urban" natural capital assets.

  This point is noted in the SEEA discussion paper (UN, 2019): *"In principle, urban green sub-classes should not duplicate natural and semi-natural classifications…as presumably the services resulting from a large urban park differ from those provided by a grassland"*.

In addition, an approach with sufficient flexibility to meet the following criteria would be useful without violating the mutually exclusive criteria (i.e. recognising that the same land area can be described by land cover and/or land use):

- **Distinguishes between structural and functional classifications for ecosystem assets:** as the European Commission's MAES initiative notes that *"often, classifications adopt a structural classification approach, a functional approach or both"* (EC, 2016). Structural classifications are based on land cover type or vegetation characteristics (e.g. grassland, trees), whereas functional classifications are based on land use types (e.g. sports ground or park). It is proposed the description / classification of assets in the Melbourne assessment combines both land cover *and* land use classifications by making it clear what the ecosystem type (e.g. forest) is but also how that ecosystem is used (e.g. plantation, openly access recreation).

The seven ecosystem types referred to in Victorian Parks account (PV and DELWP, 2014) are considered suitable candidates to form the basis of a broad asset classification within Victoria that is mutually exclusive (no overlaps), aligns with differences in ecosystem service provision and value and is also easily understood and of a reasonable number. However, in order to be suitable for this purpose, the ecosystem classification needs to be comprehensive (i.e. cover entire land area of Victoria). On further consideration of ecosystem categories used by Parks Victoria (n.d.) and in the suite of comprehensive and mutually exclusive environmental-economic accounts within the UK (ONS, 2018), it is proposed that additional ecosystems to those identified in the Victorian Parks account (PV and DELWP, 2014) are farmland and urban. The following broad ecosystem asset types therefore represent the proposed set of mutually exclusive ecosystems for which accounts could be developed in Victoria for use in the Melbourne EEA:

1. Marine
2. Alpine
3. Shrubland
4. Grassland
5. Forest/woodland
6. Coastal margins
7. Farmland
8. Freshwater and wetland
9. Urban

These ecosystem types align with major ecological vegetation classes (EVC) and the groups within the Australian Vegetation Attribute Manual version 7 (Department of the Environment and Energy, 2017). These broad asset classes represent the set of mutually exclusive ecosystems for which environmental-economic accounts could be developed in Victoria.

There is no dataset that classifies ecosystems according to the nine broad ecosystem assets in Box 1. The study team considered the following datasets to capture the extent of broad ecosystem assets within Victoria:

- **Victorian Land Cover Time Series (VLCTS)**: this provides a consistent through time, whole-of-state, spatial land cover dataset with 19 land cover classes. This dataset is comprehensive, covering the entire land area and mutually exclusive insofar as there will be no overlaps (so a given land/water area is included once);

- **Combined Biotope Classification Scheme (CBiCS) and Ecological Vegetation Classes (EVCs)**: these datasets are technical ecological classifications which have too many categories to provide a broad classification but could usefully form the hierarchy of more specific sub-habitats.

The proposed approach to capturing the extent of the nine broad assets within the Melbourne Urban EEA is to use the VLCTS database with disaggregation to narrow assets using the CBiCS, EVC and other relevant datasets where this is useful for assessing the provision of ecosystem services.

The VLCTS has 19 land cover classes, which the study team has mapped across to the nine broad assets. This mapping of VLCTS land cover classes to the broad assets has been informed by the descriptions of each class (detailed in Annex 2), as well as interrogating other datasets such as the Victorian Land Use Information System (VLUIS). For example, investigating the VLCTS and VLUIS datasets together indicates that the *Exotic pasture / grassland* land cover class areas, which are defined as ‘herbaceous pastures that are predominantly composed of nonindigenous species’ (DELWP 2020), predominantly cover farming land use areas. Therefore, this land cover class has been attributed to the *Farmland* broad asset class rather than to *Grassland*.

Table A3.1. shows the mapping of VLCTS land cover categories to the broad ecosystem asset classification in a comprehensive and mutually exclusive way insofar as the entire land area within the region is captured under both classifications and the area within the VLCTS classification maps completely across to the broad ecosystem assets.

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Table A3.1. Broad ecosystem assets based on VLCTS dataset (DELWP, 2020)

Broad assets	VLCTS land cover class
Marine	Water [a]
Alpine	Defined by altitude [b]
Shrubland	Native shrubland
Grassland	Native pasture / grassland
Forest / woodland	Treed native vegetation
	Scattered native trees
	Hardwood plantation
	Conifer plantation
	Other exotic tree cover
Coastal margins	Natural low cover
	Saltmarsh vegetation
	Mangrove vegetation
Farmland	Horticulture / irrigated pastures and crops
	Dryland cropping
	Exotic pasture / grassland
Freshwater and wetland	Wetland – perennial
	Wetland – seasonal
	Water [a]
Urban	Built environment
	Urban area
	Disturbed ground

[a] *The Water land cover class will be cut at the coastline to differentiate between marine and terrestrial water assets.*
[b] *Alpine areas will be defined as land 600 metres above sea level (RMIT, n.d.) and therefore could include all 19 VLCTS categories (in theory).*

Operationalising the ecosystem classification set out in Box A3.1. requires urban areas to be defined using spatial data in Geographical Information Systems (GIS) that can track changes in the 'urban' area over time (e.g. through built development / urbanisation). Administrative or political boundaries do not track changes in 'urban areas' and therefore should not be used (but could be used to define the assessment boundary, see Section A). The following definitions of urban areas were identified from the literature:

- The Utrecht, Netherlands assessment (Natural Capital Solutions, 2018) defines urban areas as those areas where "people live in high densities and/or where built-up infrastructure covers a major proportion of the land surface".
- The UK urban natural capital account (eftec et al, 2017) uses a GIS dataset for built-up areas to distinguish urban from non-urban areas.
- Functional urban areas (FUA) have been developed by the OECD and the EU in order to create more comparable spatial units for urban areas globally based on the city and its commuting zone (OECD, 2019).

This suggests that existing applications have defined urban areas either by density of population, density of buildings, built-up areas or commuting zones. The SEEA revision paper (UN SEEA, 2019) notes that the desired scope of urban environmental-economic accounting is not yet clear:

"Artificial surfaces are a feature of cities, but also smaller settlements such as towns and villages, and also industrial sites. A question therefore is whether some threshold should be set to determine a given area's inclusion in urban ecosystem accounts - should the scope of urban ecosystem accounts be limited to large metropolitan areas and cities? Or should it include towns and villages? Should it include all identifiable human settlements and industrial

sites? And should such a threshold be based on population or population density characteristics, buildings, or a minimum delineated area or percentage of artificial surfaces/built-up?"

Therefore, the literature review finds that there are a range of possible ways to distinguish "urban" from "non-urban" areas. Given that the Melbourne assessment is being developed with a view to potentially informing a Victoria wide urban account that is part of a wider set of integrated, mutually exclusive environmental-economic accounts that cover the entire land area of the State, consideration is given to how urban accounts could be developed beyond metropolitan areas, cities and/or areas of a certain population or building density threshold. To constrain the prospective scope of urban areas on this basis would mean some land areas would not feature in a wider set of integrated environmental-economic accounts at all (assuming that these land areas would not be captured in other accounts)[64].

The Functional Urban Areas approach is also not considered suitable for determining "urban" from "non-urban" ecosystems because it is focused on cities (e.g. OECD data for Victoria covers Greater Melbourne, Bendigo, Ballarat and Geelong) as opposed to all urban areas and the commuting region is likely to be dominated by what are conventionally considered "non-urban" areas such as grassland, forests and agricultural land. (However, FUA could be considered useful for determining the geographic boundary for large metropolitan areas on a consistent basis across the world, see Annex 2).

A3.2. Potential approach for the Melbourne EEA

The following are potential datasets that could be used to define urban areas for the Melbourne EEA:

- **Rural-Urban Interface:** defines the *outer interface* between Melbourne's developed urban and undeveloped rural land. Created using DELWP's annual Urban Development Program (UDP) data and aerial photography[65]. Available annually from 2008 – 2018, see Figure 2. (DELWP, 2018);

- **Victorian Land Cover Time Series (VLCTS)**: provides land cover time series data at 25 metre resolution across Victoria for 19 land cover classes including urban areas. Available for 5 yearly periods between 1990 and 2015 (as well as for 1987 and 2019) (DELWP, 2020d);

- **Place Area Polygon/Built Up Area**: Areas of dense/moderately dense housing and buildings with definite boundaries, part of the VICMAP VMFEAT geodatabase, see Figure 2 (DELWP, 2020a);

- **Declared urban zones:** As declared under a planning scheme in force under the Planning and Environment Act 1987, see Figure 2. These zones change over time and new zones are declared as required for relevant tax years. (SRO 2020);

- **Victorian Land-Use Mapping System (VLUIS)**: VLUIS describes the land tenure, land use and land cover for each cadastral parcel across Victoria. Urban areas partly defined using Place Area Polygon/Built Up Area dataset (DJTR, Agriculture Victoria, 2016);

- **Remotely sensed data**: High resolution satellite imagery data capable of determining artificial versus natural surfaces. This is not yet available. (DELWP, 2020b).

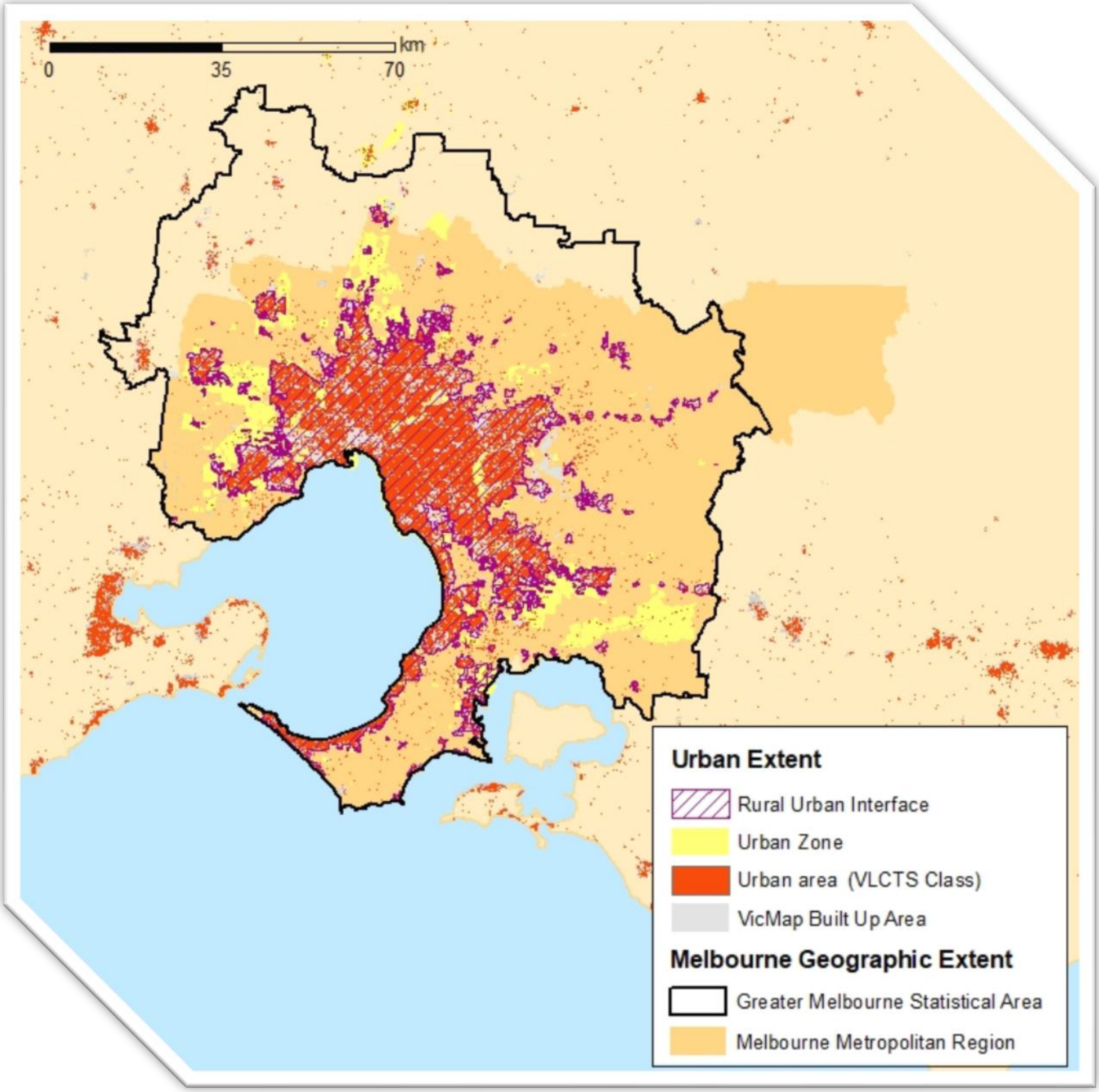
[64] Whilst the focus on defining "urban land cover" is deemed an appropriate approach to classify the entire land area to different ecosystems (including urban), further consideration should be given to differences in the physical provision and monetary value of ecosystem services from urban areas in cities compared to peri-urban and rural areas (towns and villages) and therefore the need for different methods/approaches to quantify and value these services.

[65] This dataset has been developed by an internal DELWP team and is not publicly accessible.

Unofficial

Figure A3.1 illustrates the extent of urban areas according to the different urban datasets within the Melbourne boundary and Table A3.2 sets out the pros and cons of each of the above datasets.

Figure A3.1. Potential datasets to define Melbourne's urban area [66]



[66] *VLUIS extent is not shown as it is very similar to Place Area Polygon/Built Up Area and undistinguishable from it at this scale.*

Table A3.2. Pros and cons of different options for defining Melbourne's urban area

Boundary	Pros	Cons
Rural-Urban Interface	- Has temporal coverage with annual extent data for 2008 – 2018; - Uses a standardised and consistent approach to defining 'urban'; - High resolution based on annual interpretation of aerial photography combined with parcel information; - Relies on datasets and processes that are likely to remain available into the future.	- Does not extend beyond Melbourne and Geelong into regional Victoria.
Victorian Land Cover Time Series (VLCTS) – Urban area	- Covers all of Victoria so could be useful for a state-wide urban environmental-economic account; - Provides a history of urban area change from 1987 to 2019.	- Low (25m) resolution; - Less rigorous method vs Rural-Urban Interface (uses averaged information over a 5 year period from satellites which is then modelled to map urban growth).
Place Area Polygon/Built Up Area (VicMap)	- Covers all of Victoria so could be useful for a state-wide urban environmental-economic account.	- Not the most up to date information on Melbourne's urban area; - Doesn't provide a history of urban area change.
Remotely sensed data	- Potentially a consistent and replicable approach to collecting urban extent data; - Process could be applied to historical imagery producing temporal change data; - Consistent approach state-wide.	- Not yet available; - Resolution difference between older and newer imagery; - Reliant on funding for data and analysis, no certainty on availability of future data.
Declared urban planning zones – Urban zone	- Uses readily available data and processes; - Likely to be available into the future.	- Maps urban zoning not developed urban parcels thus will include vacant lots not yet developed or made 'urban'; - Can't be used to compare change in urbanised areas over time, only urban zoned areas; - Applies to a discrete set of Melbourne local government regions, not a state-wide dataset.
Victorian Land-Use Mapping System	- Attributed with additional data on tenure, landcover and land use; - Covers all of Victoria.	- Program has no ongoing funding thus availability of future data is uncertain; - Relies on Place Area Polygon/Built Up Area to define most urban areas; - Inconsistent mapping approaches creates data uncertainty.

Urban area datasets such as those in Table A3.1. are typically based on the built environment. This aligns with the UK urban natural capital account finding that a typical definition of 'urban' includes assets such as roads and buildings, but that this definition excludes other assets such as parks, grasslands, trees and rivers (eftec, 2017).

For the purpose of environmental-economic accounting, where "urban" datasets do not capture ecosystem assets within the "urban ecosystem" it is necessary to expand the typical definition of "urban" beyond built-up areas to include urban ecosystem assets. For example, determining the geographic point at which a river running through a city starts and stops being classified as an urban river [67].This can be achieved by applying a rule to existing urban area datasets to capture urban ecosystem assets within and surrounding the built environment. The rule must ensure that all natural environment assets that are typically considered to be "urban" (i.e. an urban land use) are captured whilst minimising capture of ecosystem assets that are not typically considered "urban" [68].

The following bullet points describe the range of methods used to capture the "urban ecosystem" across the assessments reviewed:

- For the UK-wide account, administrative boundaries for metropolitan areas are not suitable to use to define urban areas because this would only partially capture all urban areas that exist nationally (e.g. urban areas in predominantly rural locations). Therefore, the UK accounts adopt a GIS-based rule[69] to define urban ecosystem areas nationally (based on built-up areas) and this rule is also applied (by the same consultancy, eftec, 2018) within the Manchester account to separate urban ecosystems from non-urban ecosystems within the Greater Manchester administrative area. This rule-based approach therefore deals with issues of scaling accounts (e.g. at national and sub-national level).

- The Wellington and Oslo assessments include non-built-up areas within their scope. This means these studies captured some broader ecosystem assets such as agricultural land, peri-urban forests, rural and coastline, in addition to the more common ecosystem assets found within built-up areas. The Oslo study suggests this is rational because the proximity of these ecosystem assets to the urban residents is an important factor in their wellbeing. This aligns with the approach taken in the UK natural capital account based on buffer zones around built-up areas which is described above.

- The Ontario, Belfast and Beam Parklands assessments focus *only* on the ecosystem assets contained within selected green areas (e.g. greenbelts, nature reserves, parklands) which sit adjacent to, but outside of the built-up area. This is not deemed appropriate for the Melbourne EEA because we need a consistent rule for distinguishing between urban and non-urban assets that can be applied across Victoria (whereas this is an ad-hoc approach which requires the person developing the account to specify which ecosystem assets are of interest).

[67] Whilst this issue could be addressed in a Melbourne specific assessment by delineating the boundary of Greater Melbourne and assuming everything within that boundary is "urban natural capital", our interest is in developing a method to identify urban ecosystems that can be replicated across the state and identify "urban ecosystem" from a wider set of integrated, mutually exclusive environmental-economic accounts. Therefore, consideration is given to how urban natural capital assets can be consistently determined (from other ecosystem types) across Victoria, including (for example) defining what are urban ecosystem assets surrounding small urban areas in regional Victoria (and what should be accounted for as non-urban ecosystem).

[68] This is not to be confused with a possible alternative approach that includes all assets that deliver ecosystem services / benefits to the urban population.

[69] The variable buffer rule was applied around the Office for National Statistics (ONS) built-up areas dataset within GIS. The buffer was scaled in proportion to the area of each polygon so that larger built-up area polygons have a greater buffer zone applied, meaning that a greater area of the surrounding natural environment is captured compared to smaller polygons. This rule essentially determines the area of other ecosystem assets to define as "urban" based on their proximity to built-up areas. This means that urban rivers and urban parks will be captured because they are close to buildings, but also that some areas not conventionally thought of as "urban" are likely to be captured such as agricultural land situated close to built-up areas.

Unofficial

Annex 4. Victorian Land Cover Time Series

The Victorian Land Cover Time Series provides a consistent through time, whole-of-state, spatial land cover data set for 7 epochs (1987-1990, 1990-1995, 1995-2000, 2000-2005, 2005-2010, 2010-2015 and 2015-19). The dataset uses Landsat satellite imagery and local calibration (or training) data. Each layer presents the most likely land cover class for that area. Victoria has 19 land cover classes. Each 25m pixel of the layers displays one of these classes. The 19 target land cover classes and their descriptions are detailed in Table A4.1.

Table A4.1. Description of land cover classes within the VLCTS

Land cover class	Description
Treed native vegetation	Native tree cover
Scattered native trees	Native trees scattered in paddocks and woodland along roadsides and streams.
Native shrubland	Native shrubland cover
Native pasture / grassland	Grasslands and pastures that are predominantly composed of indigenous species grasses and/or low chenopod shrubs. Includes grasslands that have been 'derived' through the clearing of tree and/or shrub cover.
Natural low cover	Environments that naturally have low to negligible vegetation cover such as coastal foredunes, saline lakebeds, claypans and rock-outcrops.
Wetland – perennial	Persistent, typically herbaceous cover comprised of native plant species that are tolerant of inundation or waterlogging.
Wetland – seasonal	Seasonal or ephemeral, typically herbaceous cover comprised of native plant species that are tolerant of episodic inundation or waterlogging.
Saltmarsh vegetation	Intertidal wetlands supporting native vegetation that are not mangroves
Mangrove vegetation	Intertidal native vegetation supporting mangrove (*Avicennia marina*)
Horticulture / irrigated pastures and crops	Regions of crop, pasture and parkland regularly subject to irrigation, particularly in dry months.
Dryland cropping	Regions that are regularly cropped and are not irrigated.
Exotic pasture / grassland	Herbaceous pastures that are predominantly composed of nonindigenous species.
Hardwood plantation	Tree plantations predominantly Eucalyptus globulus
Conifer plantation	Tree plantations principally Pinus radiata
Other exotic tree cover	Non-native tree-cover including conifer windbreaks, willows along streams and rivers and varied ornamental plantings.
Built environment	Persistent unvegetated areas that are the result of commercial or industrial development.
Urban area	The admixture of streets, houses and gardens that characterises much of the medium to low density urban landscape typical of Australian cities.
Disturbed ground	Persistent unvegetated areas that are the result of commercial or industrial development.
Water	Persistent surface water either fresh or saline – includes rivers, lakes, dams, wetlands and the ocean

Annex 5. Scope of socio-economic benefits within urban Melbourne EEA

This section summarises how socio-economic benefits from urban ecosystems are classified and assessed in the reviewed literature and outlines the proposed scope for the physical and monetary assessment of socio-economic flows in the Melbourne EEA based on what is feasible given the information available.

A5.1. Review of global assessments of urban ecosystems

There are a range of terms used to describe the benefits provided by the environment across the reviewed assessments, including "goods and services", "ecosystem services", "green infrastructure benefits", and "economic, social and environmental services". This mix of terms can be confusing, especially without an underpinning conceptual framework which explains the meaning of these terms. The review of literature found:

- The SEEA guidance (SEEA, 2012) recommends the use of an ecosystem service framing to link the ecological functioning of ecosystem assets to the socio-economic benefits enjoyed by society.

- For environmental-economic accounting - ecosystem accounts, the focus is on isolating and recording the ecosystems contribution, through flows of ecosystem services, to benefits[70] received (UN, 2020b). SEEA (2012) suggests the use of "logic chains" to explain the logic of these links, as was developed for in UK urban accounts (eftec, 2017) and other UK environmental-economic accounts (eftec, 2015; AECOM, 2015).

- The SEEA-EEA guidance (2020b) outlines a (non-exhaustive[71]) reference list of selected ecosystem services (in the absence of an internationally agreed classification of ecosystem services) which provides labels and descriptions for a set of key ecosystem services relevant for environmental-economic accounting. It includes both final and intermediate ecosystem services as follows:

[70] Benefits are distinguished as being either SNA benefits (produced by economic units such as food, water, energy) or non-SNA benefits (not produced by economic units such as clean air, flood protection).
[71] Other ecosystem services can be included in an environmental-economic account subject to satisfying the definition of ecosystem services.

Unofficial

Broad classification	Ecosystem service
Provisioning	Biomass provisioning (crop, timber, fish etc)
	Water supply
	Genetic material services
Regulating	Global climate regulation services
	Rainfall pattern regulation services (at sub-continental scale)
	Local (micro and meso) climate regulation services
	Air filtration services
	Soil quality regulation services
	Soil erosion control services (includes also sediment retention services)
	Water purification services (water quality amelioration)
	Water regulation services
	Flood mitigation services
	Storm mitigation services
	Noise attenuation services
	Pollination services
	Pest control services
	Nursery population and habitat maintenance services
	Solid waste remediation
Cultural	Recreation-related services
	Amenity services
	Education, scientific and research services
	Spiritual, symbolic and artistic services
	Ecosystem and species appreciation services

- The majority of applications reviewed, including the UK Urban Natural Capital Account, use the Common International Classification of Ecosystem Services (CICES) (EEA, 2018) which is a systematic classification of ecosystem services that has been developed in conjunction with the United Nations Statistical Division to comply with SEEA principles and includes broad categories of provisioning, cultural and regulating services. While CICES includes both biotic services (i.e. where there is a material ecosystem contribution) and abiotic services (i.e. where there is no distinct role of ecosystem structure and processes, SEEA-EEA, 2020b), the urban assessments reviewed focus on biotic services only and do not include other flows from the environment (such as abiotic flows).

- The Ontario Greenbelt Natural Capital assessment used the National Ecosystem Services Classification System (NESCS) developed by the U.S. Environmental Protection Agency.

- Whilst the *scope* of ecosystem services in the reviewed studies is typically reported as comprehensively as possible, only a subset of ecosystem services are quantified and valued in the reviewed literature (primarily due to data and evidence constraints). The description of ecosystem services set out in the reviewed assessments are as follows (note these are not mutually exclusive and include supporting / intermediate services), with the most common ecosystem services *assessed* in both physical and monetary terms asterisked and in bold:

- Aesthetic values
- **Air quality regulation***
- Amenity
- Biodiversity existence
- **Biodiversity habitat***
- Community cohesion
- Cultural/spiritual wellbeing
- Disturbance protection
- Education
- Erosion control
- **Flood risk regulation***
- Food
- Fibre
- Fuel
- **Global climate regulation - carbon sequestration***
- Global climate regulation - carbon storage
- **Health and wellbeing***
- Irrigation
- **Local climate regulation***
- Noise mitigation
- Nutrients
- Pest and disease control
- Pollination services
- **Recreation***
- Sense of place
- Soil regulation
- **Storm water management***
- Waste treatment
- Water provision
- **Water quality regulation***

5.2. Review of Victoria specific evidence on urban ecosystem services

Tables A5.1. and A5.2. summarise the availability of Melbourne / Victoria specific data and methods to quantify the physical provision and monetary value of the eleven ecosystem services from ecosystem assets within the Melbourne area. A literature review has been undertaken of all data, methods, reports and studies that are relevant to quantifying and valuing ecosystem services in Victoria. The outcomes from literature review will be used to:

a) Establish the scope of ecosystem services to include within the Melbourne EEA;

b) Establish the methods to estimate the physical and monetary provision of urban ecosystem services across Melbourne;

c) Identify evidence gaps / weaknesses to inform the future expansion and refinement of the account including through future research.

The focus of the literature reviewed is on studies with evidence that is expected to be of relevance to estimating and valuing ecosystem services in the Melbourne area. In order to keep the review manageable and to identify key evidence gaps, the review:

- Focused on compiling evidence sources specifically related to “highly managed and integrated” urban ecosystem assets in Melbourne (see Table 3.1.1. in Section 3). This is distinct from ecosystem service provision from broad ecosystem assets such as forests and grasslands (see below for the treatment of these broad assets where they exist within the urban area of the assessment boundary).

- Focused on compiling evidence that could be useful in developing a method to estimate the physical provision or monetary value of ecosystem services. For example, it includes studies that estimate dose-response functions that link changes in temperatures or pollutant levels (irrespective of whether that change is due to urban ecosystem assets) to impacts on human health. This information is crucial to estimating the monetary value of ecosystem services, even though it hasn’t been developed for this purpose.

Unofficial

- Includes information on the Melbourne area and from within Victoria (i.e. beyond the Melbourne area) that are judged by the study team to be applicable for transfer to the Melbourne context. It is preferable that the scientific and economic information that is applied in the analysis is specifically developed for Melbourne because Melbourne (as with any location) will have specific environmental (natural and built) and socio-economic information (i.e. beneficiary population) conditions which mean the relationship between asset status and ecosystem service provision is unique to that location. People in Melbourne (as in any location) also have specific preferences which mean the value that they place on certain benefits could differ from people in other locations.

- Excludes evidence from within Victoria that is not transferable to the Melbourne context and evidence from beyond Victoria, which could be of potential relevance to the Melbourne EEA through a process of value transfer. This includes evidence that has already been applied in Victoria specific studies in this way. Such information *could* be used to fill evidence gaps for the Melbourne EEA (as it has been in existing studies) but is a second best approach and so has been excluded from consideration in order to keep the review manageable and to identify key evidence gaps.

- Excludes information on broader "urban ecosystem assets" (e.g. urban forest, grassland, urban freshwaters)[72]. Estimating and valuing the provision of ecosystem services from these broader urban ecosystem assets is likely to require different methods to those adopted for "highly managed and integrated assets" due to their specific characteristics and location (e.g. urban forests require different approaches to street trees). It is proposed that these alternative methods are likely to be consistent with those used to develop broad ecosystem asset accounts (although the proximity of these assets to urban populations should be considered in the methods adopted where this is a key driver of the physical provision and/or value of ecosystem services) and for these assets the following sources will be consulted:

    - **Coastal assets**: DELWP (2016) Marine and Coastal Ecosystem Accounting: Port Phillip Bay; and DELWP and Parks Victoria (2015) Valuing Victoria's Parks[73]
    - **Farmland:** Deloitte (2016) The economic contribution of Melbourne's foodbowl – data is for 2010/11;
    - **Forests**: DELWP (2019) Ecosystem services from forests in Victoria;
    - **Freshwater**: Cooper et al. (2016) The Value of Melbourne's Waterways;
    - **Marine:** DELWP (2016) Marine and Coastal Ecosystem Accounting: Port Phillip Bay.

    There are some broad ecosystems for which existing assessments have not been undertaken and this will remain an evidence gap for future research including alpine, shrubland and grassland ecosystems (all of which could technically fall within the geographic boundary of an urban EEA, depending on how that boundary is defined, see Annex 2 and 3).

[72] The urban boundary is defined with the intention of capturing all ecosystem assets that are typically considered to be urban.

[73] Coastal recreation (fishing/boating) in Port Phillip.

Unofficial

Table A5.1. Potential sources of information for estimating physical provision of urban ecosystem services in Melbourne

Ecosystem service	Description	Metric (per year)	Geog. Scope	Asset	Source	Year
Air filtration	Capture of pollutants	tonnes	Melbourne	Trees	Jayasooriya et al. (2017) Green infrastructure practices for improvement of urban air quality	2017
	Capture of pollutants	tonnes	City of Melb. & Hume	Street trees	Fairman et al (2010) Using iTree STRATUM to estimate the benefits of street trees in Melbourne, Victoria	2010
	Capture of pollutants / Deposition rates	$/tonne	Melbourne's west	Tree canopy	Jones and Ooi (2014) in City of Melbourne (2019) Valuing Green Guide	2014
	Link air pollution to health outcome	Dose-response	Victoria	n/a	Aurecon (2018) AV / ZEV Environmental & Health Impact Assessment	2018
Education	Number of educational visits	Number	Melbourne	Green-blue infra.	Victorian Department for Education and Training (DET) Student Activity Locator database	TBC
	Number of educational visits	Number	Melbourne	Metro. parks	Parks Victoria	TBC
Flood mitigation	Reduce stormwater runoff due to GBI	GL	Melbourne	Metro. parks	MJA (2014) Valuing the Water Services provided by Victoria's Parks	n.d.
	Flow reduction / water conservation (eWater MUSIC model)	kL	City of Yarra	Green infrastructure	E2DESIGNLAB (2018) Embedding Green Infrastructure Economic Framework	2018
	Reduced rainfall runoff due to GBI	% retention of water	Melbourne	Green roofs	Jayasooriya & Ng (2013) in City of Melbourne (2019) Quantifying benefits of Green Infrastructure in Melbourne	n.d.
		% retention of water	Melbourne	Green roofs	Szota et al. (2017 and in prep) in City of Melbourne (2019) Quantifying benefits of Green Infrastructure in Melbourne	n.d.
		% reduce peak flow	Melbourne	Green roofs	Meek et al. (2015) in City of Melbourne (2019) Quantifying benefits of Green Infrastructure in Melbourne	n.d.
	Flood mitigation	$	City of Melb. & Hume	Street trees	Fairman et al (2010) Using iTree STRATUM to estimate the benefits of street trees in Melbourne, Victoria	2010
Biomass provisioning - Food	Food yield	tonnes	SA4 level	Urban farms	ABS Agricultural Commodities, Australia, 2017-18	2017-18
	Food yield	kilograms	Domestic gardens	Gardens	Zainuddin & Mercer (2014) Domestic residential garden food production in Melbourne, Australia	2012-13
	Food yield	kilograms	Rooftops	Bee hives	Melbourne City Rooftop Honey (2020) The Project	2020
	Households producing food	%	Victorian	Gardens	Wise (2014) Grow your own. The potential value and impacts of residential and community food gardening.	n.d.
Global climate regulation	Rate of carbon sequestration	tonnes/ha	Victoria	Green infrastructure	DELWP and Parks Victoria (2015), Valuing Victoria's Parks: Accounting for ecosystems and valuing their benefits	n.d.
	Rate of carbon sequestration	tonnes/ha	Port Phillip Bay	Blue infrastructure	DELWP (2016), Marine and Coastal Ecosystem accounting: Port Phillip Bay	n.d.
	Rate of carbon sequestration	tonnes/ha	Victoria	Green infrastructure	DELWP (2019), Ecosystem Services from Forests in Victoria: Assessment of Regional Forest Agreement Regions	n.d.
	Rate of carbon sequestration	tonnes/ha	North-Central Vic.	Green space with trees	England et al. (2006). Rates of carbon sequestration in environmental plantings in north-central Victoria	n.d.
	Rate of carbon sequestration	$	City of Melb. & Hume	Street trees	Fairman et al (2010) Using iTree STRATUM to estimate the benefits of street trees in Melbourne, Victoria	2010
	Carbon storage	tonnes/tree	Inner Melbourne	Trees	Moore (2009) People, Trees, Landscapes and Climate Change	2009
	Change in temperatures due to GBI	Dose-response	Melbourne	Park	Al-Gretawee et al. (2016) The cooling effect of a medium sized park on an urban environment.	2015
		Dose-response	Melbourne	n/a	Chen et al (2014) Urban vegetation for reducing heat related mortality	2009-50
		Dose-response	Melbourne	Urban trees	City of Melbourne (2014) Urban forest strategy – Making a great city greener 2012-2032. Melbourne, Australia.	2009
		Dose-response	Melbourne	Urban trees	CRCWSC (2017) The climatic benefits of green infrastructure – Industry Note	2014
		Dose-response	Melbourne	Green roofs	Meek et al. (2015) in City of Melbourne (2019) Quantifying benefits of Green Infrastructure in Melbourne	n.d

Unofficial

Local climate regulation		Dose-response	Melbourne	Green roofs	Jamei and Rajagopalan (2017) in City of Melbourne (2019) Quantifying benefits of Green Infrastructure in Melbourne	n.d.
		Dose-response	UK	Waterways	Hathway et al. (2012) The interaction of rivers and urban form in mitigating the Urban Heat Island effect	2010
	Heat-mortality and morbidity relationships	Dose-response	Melbourne	n/a	AECOM (2012) Economic Assessment of the Urban Heat Island Effect	2009
		Dose-response	Victoria	n/a	Dept. Human Services (2009) January 2009 Heatwave in Victoria: An Assessment of Health Impacts	2009
		Dose-response	Victoria	n/a	Dept. of Health (2011) The population health impacts of heat	Various
		Dose-response	Melbourne	n/a	Nicholls et al. (2008) A simple heat alert system for Melbourne, Australia	1979-01
		Dose-response	Melbourne	n/a	Loughnan et al. (2013) A spatial vulnerability analysis of urban populations during extreme heat events in Aus. capital	Various
		Dose-response	Melbourne	n/a	Loughnan et al. (2010) The effects of summer temperature, age and socioeconomic circumstance on AMI admissions	1999-04
		Dose-response	Melbourne	n/a	Frontier (2019) Health benefits from water-centric liveable communities	Various
	Heat - GVA relationship	Dose-response	Melbourne	n/a	NCEconomics (2018). Heatwaves in Vic.: a vulnerability assessment.	2018-50
		Dose-response	Melbourne	GBI	CRCWSC (2019) Estimating the economic benefits of Urban Heat Island mitigation – Economic analysis	2014-17
	Heat - Energy use reduction	Dose-response	City of Melb. & Hume	Street trees	Fairman et al (2010) Using iTree STRATUM to estimate the benefits of street trees in Melbourne, Victoria	2010
		Dose-response	Melbourne	n/a	AECOM (2012) Economic Assessment of the Urban Heat Island Effect	2009
		Kg CO_2e per KwH	Melbourne	n/a	City of Melbourne (2019) Valuing Green Guide	
	Change in other benefits	Dose-response	Melbourne	n/a	AECOM (2012) Economic Assessment of the Urban Heat Island Effect	2009
	Baseline heat exposure/vulnerability	°C (GIS)	Melbourne	Tree, shrub and grass	DELWP et al (2019) Mapping & analysis of vegetation, heat & land use	2014-18
Noise attenuation	Baseline exposure to noise	Decibels	Melbourne	n/a	WSP (2013) Melbourne estimation of noise exposure	n.d.
Recreation-related (tourism and local)	Overnight visits and daytrips	Number	Melbourne	Parks	Deloitte (2014) Valuing the Tourism Services provided by Vic. Park	2010-11
	Park attributable tourism jobs	Number jobs	Melbourne	Parks	Deloitte (2014) Valuing the Tourism Services provided by Vic. Park	2010-11
	Park active visits/visits/visitors/activity	Number	Victoria	Urban parks	DELWP and Parks Victoria (2015), Valuing Victoria's Parks: Accounting for ecosystems and valuing their benefits	2012 -13
	Waterway visits	Number visits	Victoria	Parks Vic. water assets	DELWP and Parks Victoria (2015), Valuing Victoria's Parks: Accounting for ecosystems and valuing their benefits	2012 -13
	Park area - recreation relationship	Dose-response	Melbourne	Parks	King et al (2012) Does parkland influence walking? The relationship between area of parkland and walking trips in Melbourne, Australia	2003
	Nature based outdoor activities	Number of times	Victoria	Nature	MJA (2016) Victoria's nature-based outdoor economy	n.d.
Water purification	Reduced nitrogen loads	Tonnes of nitrogen	Melbourne	Metro. parks	MJA (2014) Valuing the Water Services provided by Vic. Parks.	n.d.
		Grams per m^2	Port Phillip Bay	Green roofs	City of Melbourne (2019) Valuing Green Guide	2019
	Reduced nitrogen/suspended solids/ phosphorous (eWater MUSIC model)	kg	City of Yarra	Green infrastructure	E2DESIGNLAB (2018) Embedding Green Infrastructure Economic Framework	2018
Water supply	Water provision / filtration / storage	ML	Central Highlands	Various	Vardon et al. (2019) Accounting and valuing the ecosystem services related to water supply in the Central Highlands of Victoria, Australia	2015

Table A5.2. Potential sources of information for estimating monetary valuation of urban ecosystem services in Melbourne

Ecosystem service	Description	Metric	Geog. Scope	Asset	Source	Year
Air filtration	Damage costs - health	$/tonne	Melbourne	n/a	PAE Holmes (2013) Methodology for valuing the health impacts of changes in particle emissions	2013
	Damage costs - health	$/tonne	Australia	n/a	Parry et al. (2014) Getting energy prices right: From principle to practice	2014
	Health and welfare	$/tonne	Melbourne's west	Tree canopy	Jones and Ooi (2014) in City of Melbourne (2019) Valuing Green Guide	2014
Amenity	Value of proximity to parks	$ property prices	Melbourne	Parks	IV and Aither (2018) What makes a locality attractive? Estimates of the amenity value of parks for Victoria	2018
	Bundle of ecosystem services	$	Greater Melbourne	Urban parks	DELWP and Parks Victoria (2015) Valuing Victoria's Parks	2012-14
	Value formula: tree characteristics	$ appraisal [a]	City of Melbourne	Urban trees	City of Melb (n.d.) Tree valuation in the city of Melbourne	n.d.
	Bundle of ecosystem services	$ unspecified	City of Melbourne	Street trees	Moore, G. (2009) Urban Trees: Worth More Than They Cost	2009
	Bundle of ecosystem services	$ property prices	City of Brimbank	Park	Mekala et al. (2015) Valuing the Benefits of Creek Rehabilitation	2015
	Bundle of ecosystem services	$ property prices	City of Moreland	Open space, water, golf	NCEconomics (2019) The economic value of open space and urban	2019
	Bundle of ecosystem services	$ welfare	Melbourne	Urban waterways	Cooper et al. (2016) The Value of Melbourne's Waterways	2016
	Bundle of ecosystem services	$ welfare	Victoria	Waterways	Bennett et al (2008) The economic value of improved environmental health in Victorian rivers	2008
	Bundle of ecosystem services	$ welfare	Melbourne	Blue and green space	Brent et al (2016) Valuing Environmental Services Provided by Local Stormwater Management;	2013-14
	Biodiversity, erosion, pests, litter	$ welfare	Melbourne	Waterways	Brent et al (2016) Valuing Environmental Services Provided by Local Stormwater Management;	2013-14
Education	Expenditure on school trips to outdoors	$	n/a	Nature	Australian Camping Association (2018) Prices and Occupancy Survey Report	2018
Flood mitigation	Flood mitigation	$	City Melb. & Hume	Street trees	Fairman et al (2010) Using iTree STRATUM to estimate the benefits of street trees in Melbourne, Victoria	2010
	Less flood detention/storage infra.	$ avoided cost	Melbourne	Metro. parks	MJA (2014) Valuing the Water Services provided by Vic. Parks.	n.d.
	Reduced stormwater	$ unspecified	City of Melbourne	Street trees	Moore, G. (2009) Urban Trees: Worth More Than They Cost	2009
	Prevention of flash flooding	$ welfare	Melbourne	n/a	Brent et al (2016) Valuing Environmental Services Provided by Local Stormwater Management;	2013-14
Biomass provisioning - Food	Agricultural productivity	$ GRP	Melbourne LGA's	Urban farmland	Deloitte (2016) The economic contribution of Melbourne's foodbowl	2010-11
	Agricultural productivity	% crops	Domestic gardens	Gardens	Zainuddin & Mercer (2014) Domestic residential garden food production in Melbourne, Australia	2012-13
	Agricultural productivity	$ / kg	Rooftops	Hives	Melbourne City Rooftop Honey (2020) The Project	2020
Global climate regulation	Average abatement cost	$ shadow price	n/a	n/a	BDA Group (2015) Valuing the benefits of Victorian waterway management	n.d.
	Market price / social costs	$ market/social cost	n/a	n/a	DELWP and Parks Victoria (2015), Valuing Victoria's Parks: Accounting for ecosystems and valuing their benefits	n.d.
	Market price / social costs	$ market/social cost	n/a	n/a	DELWP (2016), Marine and Coastal Ecosystem accounting: Port Phillip Bay	n.d.
	Market price / social costs	$ market/social cost	n/a	n/a	DELWP (2019), Ecosystem Services from Forests in Victoria: Assessment of Regional Forest Agreement Regions	n.d.
	Speculative carbon price	$ unspecified	n/a	n/a	Fairman et al (2010) Using iTree STRATUM to estimate the benefits of street trees in Melbourne, Victoria	2010
	Social costs	$ social cost	n/a	n/a	Hope (2006) The social cost of carbon: what does it actually depend on?	2006
	Market price / social costs	$ market/social cost	n/a	n/a	Mekala et al. (2015) Valuing the Benefits of Creek Rehabilitation	2015
	Market price	$ market	n/a	n/a	Moore, G. (2009) Urban Trees: Worth More Than They Cost	2009
Local climate regulation	Decreased peak urban temp's	$ welfare	Melbourne	Blue space	Brent et al (2016) Valuing Environmental Services Provided by Local Stormwater Management	2014
	Reduced mortality and morbidity	$ VSL/cost	Melbourne	n/a	AECOM (2012) Economic Assessment of the Urban Heat Island Effect	2009

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		$ VSL/cost	W Melbourne	n/a	CRCWSC (2018) Economic value of urban heat mitigation	2015-17
	Improved productivity	$ wages	W Melbourne	n/a	CRCWSC (2018) Economic value of urban heat mitigation	2018
		$ GRP	Melbourne	n/a	NCEconomics (2018). Heatwaves in Vic.: a vulnerability assessment.	2018-50
	Energy use reduction	$ avoided costs	Western Melbourne	n/a	CRCWSC (2018) Economic value of urban heat mitigation	n.d.
		$ TBC	City Melb. & Hume	Street trees	Fairman et al (2010) Using iTree STRATUM to estimate the benefits of street trees in Melbourne, Victoria	2010
		$ avoided costs	Melbourne	n/a	AECOM (2012) Economic Assessment of the Urban Heat Island Effect	2009
		$ avoided costs	City of Melbourne	Street trees	Moore, G. (2009) Urban Trees: Worth More Than They Cost	2009
	Prolonged life of bitumen paths	$ per m^2	Australian city	Urban trees	Moore, G. (2009) Urban Trees: Worth More Than They Cost	2009
	Other benefits (to crime, infrastruct.)	$	Melbourne	n/a	AECOM (2012) Economic Assessment of the Urban Heat Island Effect	2009
Noise attenuation	Value of noise regulation	$ welfare	Unspecified	n/a	Aurecon (2018) AV / ZEV Environmental & Health Impact Assessment	2018
Recreation related (tourism and local)	Waterway recreation	$ expenditure	Victoria	Rivers	BDA Group (2015) Valuing the benefits of Victorian waterway management	n.d.
	Link physical inactivity to health costs	$ costs	Australia	n/a	Cadilhac et al. (2011) The economic benefits of reducing physical inactivity: an Australian example	2008
	Tourism and exports	$ revenue	Melbourne	Public parks & gardens	CRC for irrigation future (2008) Irrigation of Urban Green Spaces...	1998
	Physical activity	$ avoided cost	Unspecified	n/a	Dedman (2011) in Frontier (2019) and Mekala et al. (2015)	n.d.
	Tourism	$ GVA	Metro. Melbourne	Parks	Deloitte (2014) Report on Valuing the Tourism Services provided by Victorian Parks	2010-11
	Park recreation	$ cost/welfare	Victoria	Parks	DELWP and Parks Victoria (2015) Valuing Victoria's Parks	2012-14
	Coastal recreation (fishing/boating)	$ total econ. value	Port Phillip	Coastal assets	DELWP and Parks Victoria (2015) Valuing Victoria's Parks	2012-14
	Physical activity	$ avoided cost	Australia	n/a	Medibank (2008) The cost of physical inactivity	2008
	Park recreation	$ welfare/avoid cost	City of Brimbank	Park	Mekala et al. (2015) Valuing the Benefits of Creek Rehabilitation	2015
	Outdoor recreation	$ costs/GVA/welfare	Victoria	Nature	Marsden Jacob (2016) Victoria's nature-based outdoor economy	n.d.
	Outdoor recreation	$ welfare/cost/GVA	City of Moreland	Open space, water,golf	NCEconomics (2019) The economic value of open space and urban	2019
	Park recreation	$ welfare	Victoria	Metro parks	Read et al (1999) Economic assessment of the recreational values of Victorian Parks.	n.d.
Water purification	Reduced filtration infrastructure	$ avoided cost	Melbourne	Metro. parks	MJA (2014) Valuing the Water Services provided by Vic. Parks.	n.d.
		$ avoided cost	Melbourne	n/a	Payne et al (2015) Adoption Guidelines for Stormwater Biofiltration	2014
	Cost of offsite treatment based on past stormwater treatment works	$ / kg / yr (avoided cost)	Melbourne	Green infrastructure	Melbourne Water (2013) in E2DESIGNLAB (2018) Embedding Green Infrastructure Economic Framework	2013
	Nitrogen interception	$ avoided cost	Melbourne	Green roofs	Melbourne Water quoted in City of Melbourne (2019) Quantifying benefits of Green Infrastructure in Melbourne	n.d.
Water supply	Exemptions from water restrictions	$ welfare	Melbourne	Green infrastructure	Brent et al (2016) Valuing Environmental Services Provided by Local Stormwater Management	2013/14
	Retail cost for potable water	$ price	Melbourne	n/a	City of Melbourne (2019) Valuing Green Guide	n.d.
	Non-residential recycled water cost	$ price	Melbourne	n/a	City of Melbourne (2019) Valuing Green Guide	n.d.
	Water provision / filtration / storage	$ replacement cost	Central Highlands	Various	Vardon et al. (2019) Accounting and valuing the ecosystem services related to water supply in the Central Highlands of Victoria, Australia	2015

[a] The basic monetary value of a tree is taken from the internationally accepted table of values devised by the American Council of Tree and Landscape Appraisers (ACTLA) and the International Society of Arboriculture.

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The evidence in Tables A5.1. and A5.2. is structured by ecosystem service but could alternatively be structured according to ecosystem asset type. Figures A5.1. and A5.2. are matrices which provide an indication of the depth of evidence on the physical provision and monetary value respectively, of ecosystem services by asset types based on the number of studies identified as being *potentially* relevant for informing the development of a Melbourne EEA.

These matrices can be used to inform the scope of ecosystem services to assess in the initial Melbourne EEA as well as identify evidence gaps for future research and so **all** ecosystem services are included in Tables A5.1. and A5.2. The following caveats should be noted when interpreting the numbers in Figures A5.1. and A5.2. for informing the scope of ecosystem services to include / areas for future research:

- The number of studies do not represent unique studies as it includes some reports that are literature reviews (of the other studies listed) and some analyses which rely on the same sources of evidence. So, an ecosystem service with 10 references has a high number of references but all these references could (hypothetically) rely on 2 underlying sources of evidence. Whereas another ecosystem service with 3 references might be to 3 unique sources of evidence. The numbers should therefore be interpreted as being representative of the level of interest in and broadly (but not definitively) the scale of evidence for that ecosystem service/ecosystem asset in Melbourne.

- The *number* of studies identified for each ecosystem service / asset is reported without consideration of the *quality* of these studies for assessing ecosystem services. This means that:

  - The extent to which the identified information will facilitate a full and accurate quantification or valuation of ecosystem service is unclear, it might only be part of the range of evidence that is needed.
  - An assessment of ecosystem services / assets is not necessarily straightforward / possible where the number of studies of *potential* relevance is high, but it provides an indication that there is at least some information to work from.
  - There may still be a significant need for additional research for that ecosystem service / asset to fill key evidence gaps even when the number of studies identified is high.

- The studies identified are from the reviewed literature and there may be updated (i.e. more recent) versions of these, especially where data is collected on a periodic basis.

- Some studies have information that is relevant for assessing ecosystem services in Melbourne are not tied to a specific asset type (e.g. recreation data might be for the region as a whole), and these studies are included in the column “Non-asset specific info.”.

- The numbers are not based on a comprehensive review of evidence but serve as an indication of the depth of relevant information for developing an environmental-economic account for the Melbourne EEA and can help inform evidence gaps for future research.

- Bio-physical and socio-economic models that have been built with Victorian specific information are included as relevant evidence, including DELWP’s Environmental Systems Modelling Platform (EnSYM) [74] and IV and Aither’s hedonic valuation model.

[74] The Environmental Systems Modelling Platform (EnSym) is a computer software package originally designed to quantify the environmental benefits of on-ground conservation and revegetation works. Environmental impacts reported by EnSym cover water quantity and quality, plant physiology, native vegetation and groundwater. EnSym can be used to assess the environmental impacts of land use changes and to produce information and accounts that align with the United Nations System of Environmental-Economic Accounting (SEEA).

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Figures A5.1. and A5.2. show:

- Evidence on physical provision:

  a. Was not found for amenity[75] and water provision and is sparse for education, air quality, noise regulation and water quality regulation from ecosystem assets in Melbourne;
  b. Was not identified at all for road verges and urban wetlands in Melbourne and is sparse for private gardens, rivers and green roofs/walls as ecosystem assets in Melbourne;
  c. Is highest for local climate regulation as an ecosystem service, which is being driven by non-asset specific information (see Table A5.1) that is needed to construct an analysis (e.g. dose-response functions linking reductions in heat to changes in health outcomes);
  d. Is highest for public parks and gardens and street trees as ecosystem assets with much non-asset specific information (i.e. references to “green infrastructure” or dose-response functions which capture the effect of temperature changes (for whatever reason) on socio-economic outcomes).

- Evidence on monetary value:

  e. Is highest for recreation and local climate regulation and sparse for education, noise regulation, water quality regulation and water provision from ecosystem assets in Melbourne;
  f. Was not found for road verges and is sparse for green roofs and walls, private gardens and urban wetlands in Melbourne;
  g. Is highest for street and park trees, public parks and gardens and for non-asset specific information that is needed to construct an analysis (e.g. value of a statistical life, avoided cost of productivity losses and medical treatment which are not tied to specific ecosystem assets).

The study team found that there is a lack of peer reviewed estimates of the economic value of urban ecosystem services in Victoria. This conclusion has led to existing assessments of the value of urban ecosystems in Victoria to apply “value transfer” from previous studies outside of the State of Victoria. This approach is not proposed for the Melbourne EEA, in order to facilitate evidence gaps being identified and addressed through primary research.

[75] The evidence on the amenity value of green space is focused on monetary provision rather than physical provision. This reflects the method typically used to value amenity (i.e. hedonic pricing method) which relies on the market price of residences and the proximity of those residences to green space (which is a “spatial configuration” of ecosystem assets metric and should be included within the condition account).

Figure A5.1. Depth of relevant evidence identified on physical provision of ecosystem services from urban ecosystem assets in Melbourne

		Integrated green infrastructure		Highly managed grassland			Blue infrastructure		GBI	Total
		Green roofs and walls	Street and park trees	Public parks and gardens	Private land / gardens	Road verges	Rivers and lakes	Wetlands / coasts	Non asset specific info.	
Ecosystem service	Air filtration		2							**2**
	Amenity									**0**
	Education			1					1	**2**
	Flood mitigation	3	1	1						**5**
	Biomass provision - Food	1		1	2					**4**
	Global climate regulation		2	1			1		2	**6**
	Local climate regulation		3	2			1		12	**18**
	Noise attenutation								1	**1**
	Recreation			4			1		1	**6**
	Water purification			1						**1**
	Water supply									**0**
Total		**4**	**8**	**11**	**2**	**0**	**3**	**0**	**17**	

Figure A5.2. Depth of relevant evidence identified on monetary value of ecosystem services from urban ecosystem assets in Melbourne [a]

		Integrated green infrastructure		Highly managed grassland			Blue infrastructure		GBI	Totals
		Green roofs and walls	Street and park trees	Public parks and gardens	Private land / gardens	Road verges	Rivers and lakes	Wetlands / coasts	Non asset specific info.	
Ecosystem service	Air filtration								3	3
	Amenity		1	3			3		2	9
	Education								1	1
	Flood mitigation		2	1					1	4
	Biomass provision - Food	1			1				1	3
	Global climate regulation								8	8
	Local climate regulation		3				1		7	11
	Noise attenutation								1	1
	Recreation			5			1	1	5	12
	Water purification			1					1	2
	Water supply								1	1
Totals		1	6	10	1	0	5	1	31	

[a] Studies that are included within Figures A6.1 and A6.2 are deemed to be potentially relevant for the purpose of developing an urban Melbourne environmental-economic account (i.e. those included in Tables A6.1 and A6.2, it is not all studies that have been reviewed as part of this study.

Annex 6. Supply and use of ecosystem services

The SEEA guidance (UN et al., 2012) recommends reporting the “economic unit” and “ecosystem type” that is supplying and using ecosystem services (UN et al., n.d) as follows:

- Economic units are defined as industrial sectors (e.g. agriculture, forestry and fisheries; tourism), government and households.

- The “supply” of ecosystem services arises from ecosystem types (forest produces biomass and recreational opportunities). SEEA guidance (SEEA EEA TR, n.d) suggests “economic units cannot supply ecosystem services” which is true from an ecological perspective, but from a socio-economic perspective it is economic units that own and manage those ecosystem assets that underpin the supply of ecosystem services. Understanding the amount and proportion of ecosystem services “supplied” by ecosystem assets under different ownership (public versus private) is important from a policy perspective;

- Economic units “use” ecosystem services as an input to the production of goods and services (e.g. biomass for timber) from economic units (forestry industry) or as a final consumed benefit (e.g. recreation). Policy makers are interested in distribution of ecosystem asset and ecosystem service use (e.g. access and use of green space) across socio-economic groups so the study team will consult DELWP policy makers on whether it would be of value to reporting this alongside the more aggregated “households”.

DELWP’s (2016) Port Phillip Bay account notes how the boundaries of marine and coastal assets are generally less clear (compared to terrestrial assets) which makes attributing ecosystem service provision to specific assets, owners (private or public entities) and users difficult. This difficulty in assigning ecosystem service value to “users” is compounded by the “common pool” nature of many marine resources / ecosystem services whereby nobody can feasibly be excluded from the use/benefits of these resources (i.e. at a reasonable cost), yet overuse can result in asset degradation. For example, the waste assimilation ecosystem service provided within Port Phillip Bay benefits anyone who is (directly or indirectly) polluting waterways (as they do not bear the external costs of their polluting activity) as well as the range of users (and uses) benefitting from improved water quality. Further work is needed to consider how best to incorporate the concept of common pool resources within the supply and use account.

Valuing Victoria’s Parks account describes for each ecosystem service the direct beneficiaries and end users/ final beneficiaries which is a useful approach to adopt where these are not the same (e.g. water filtration services benefits economic sectors abstracting water as it results in lower treatment costs which also benefits consumers who have to pay less for goods and services provided by those sectors).

The US urban environmental-economic account developed by Heris et al (2021) estimates the physical and monetary supply of energy savings (due to urban cooling) and stormwater control (rainfall interception) by ecosystem type (i.e. supply) and distributes these values estimates across uses based on land uses (i.e. all avoided stormwater control costs are used by wastewater treatment plants).

Table A6.1. outlines potential data sources that could be used to develop the supply and use tables for the urban Melbourne EEA if information is required on asset ownership.

Table A6.1. Identified datasets to inform development of supply and use tables for Melbourne EEA

Data description	Metric	Type	Geographic Scope	Source	Year
Ownership of open space by different public bodies and private total (excluding gardens)	Ha	Spatial	Metropolitan Melbourne	VPA's Metropolitan Open Space Network Portal) in The Nature Conservancy and Resilient Melbourne (2019) Living Melbourne	n.d.
Ownership by industrial sector	Ha	Spatial	Greater Melbourne	DELWP et al (2019) Mapping & analysis of veg., heat & land use	2014-18
Ownership of private gardens	Ha	Spatial	Metropolitan Melbourne	VPA (2016), Metropolitan Open Space Network	2016
Ownership by clubs (club goods-golf, MCG)	Ha	Spatial	Metropolitan Melbourne	VPA (2016), Metropolitan Open Space Network	2016

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Annex 7. Practical and technical considerations

This section summarises the proposed approach to tackling some practical issues with developing environmental-economic accounts including the appropriate information to use and technical considerations including how to define the measurement baseline, what assessment year to use and how to estimate the value of an asset.

A7.1. Establishing appropriate data for the account

SEEA guidance (UN et al, 2012) suggests environmental-economic accounts should be developed on a spatially explicit basis, mapping the status of assets and the physical and monetary value of ecosystem services across space (and time) at high resolution (e.g. Basic Spatial Units of 1km^2, see Box A7.1.).

Box A7.1. Framework for delineating spatial areas in environmental-economic accounts (DELWP, 2016)

The framework for delineating spatial areas for environmental-economic accounting consists of ecosystem assets (EA), basic spatial units (BSU) and geographical areas (GA). Conceptually, ecosystem assets are contiguous areas (collections of BSUs) of a single ecosystem type (e.g. an area of seagrass beds).

Typically, accounting will be done for a geographic area that may include multiple ecosystem assets and only part of some ecosystem assets (i.e. only part of a seagrass ecosystem assets may be inside a specific geographic accounting area). Using a grid of basic spatial units allows for aggregation to different boundaries for different purposes.

The development of spatially explicit accounts at localised scales (e.g. 1km^2) as per the UN SEEA guidance (2012) is preferable as it facilitates greater analytical insight than accounts that are developed in tabular form at aggregated scales including:

- Improved communication of the significance of ecosystem service provision in a given location.
- Understanding differences in the distribution of ecosystem asset status and productivity across space (and time).
- Understanding the synergies and trade-offs across ecosystem services associated with changing land use / management / policies in a given location.
- Spatially explicit prioritisation of ecosystem assets / services (e.g. through planning).
- Targeting habitat creation/restoration (e.g. through strategic policy decisions).
- Targeting grant allocation / budget investments.
- Risk identification (e.g. of 'hotspots' for pests and disease)

However, such highly localised accounts might not be practical or proportionate to produce where data is not available at high resolutions / in GIS format. This point is noted in the SEEA-EEA (2020a) guidance which states that detailed spatial data is not essential:

"In concept, where compilation of ecosystem services is undertaken using fine level spatial data, it would be possible to present information on the supply and use of ecosystem services for each individual ecosystem. However, in practice, there is no requirement for reporting at this level of detail, especially for accounts covering a national scale or large areas within a country."

The range of environmental, social and economic information required to develop SEEA compliant accounts is typically available at specific administrative scales such as country, state or city with data disaggregated to more

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localised scales (and in GIS) being available when this is important for the local and central government bodies who have collected it (i.e. data is collected for reasons other than environmental-economic accounting).
Where information *is* available at localised scales / "disaggregated" at high resolution (e.g. by small area polygons or $1km^2$ in GIS) then it may be possible to map the status of assets and physical and monetary value of ecosystem services at this scale within the assessment boundary. This might require the use of bio-physical models to combine data sources and assumptions to produce justifiable estimates (based on a degree of robustness). The feasibility of such modelling will depend on the information and resources (time and skills) available.

However, where information is only available at more aggregated scales (e.g. country, state or city level), it is not appropriate to disaggregate this information to a more localised scale / resolution (e.g. $1km^2$) because this will not deliver robust estimates / it will misrepresent the information. In this case, it may be more appropriate to pursue an "aggregated" approach which reports on the condition and productivity of assets within a defined geographic region. The use of "summary-level" (aggregated or "top-down") information is noted within the SEEA-EEA Revision guidance:

"Where top-down methods are used, for example where ecosystem service flows are based on aggregate visits to national parks or total volumes of timber harvested, the attribution to ecosystem type may be more generic or stylised and there will be no accompanying map outputs." (SEEA-EEA, 2020a)

"Certain indicators can provide useful summary-level information on the state and condition of urban areas. For example, the change in extent of lands converted from natural or seminatural ecosystem types to residential areas with associated infrastructures, tracked over time, provides a snapshot of urban expansion and ensuing loss of natural and semi-natural areas. Other related indicators could focus on the concept of land degradation (e.g., percentage of contaminated or brownfield areas and reclaimed areas). Indicators drawn from these accounts can also track the role urban green and blue spaces play in providing ecosystem services, including moderating air and water pollution and mitigating heat islands, and can support the measure of accessibility to green and blue spaces. (SEEA-EEA, 2020)

An aggregated ("top-down") approach has been pursued by DELWP and PV (2015) in developing the account for Victoria's Parks with accounting tables reporting information for the entire parks network. This was also the approach taken in the UK urban accounts, which reported figures for the country (UK or GB depending on data available) in tabular form without any associated spatial mapping at local scale / high resolution. The UK account also developed estimates of ecosystem service provision for Greater Manchester using the same approach to that undertaken for the UK scale using locally specific datasets. This illustrates how methods to estimate ecosystem service provision can be applied to different scales (i.e. country and city).

Whilst the preference is to develop a Melbourne EEA with a strong spatial framing on which data of varying resolutions can be overlayed, constraints on the data and methods available could limit the extent to which this is feasible / proportionate for all sub-accounts. Data for stock accounts (i.e. ecosystem asset extent and condition) is more likely to be available on a spatial basis (i.e. in GIS format) than information for flow accounts (physical provision and monetary value of ecosystem services). In order to not constrain account development to geographic locations where highly localised spatial data is available or can be estimated with an acceptable level of robustness, it is considered appropriate for accounts to be developed at a resolution that is commensurate with data collection / appropriate given data available. This means that the Melbourne EEA will use the best available information to adhere as closely as possible to the strong spatial framing that is encouraged under the SEEA-EEA statistical standard but will include non-spatially disaggregated (top-down) information where appropriate and useful for informing policy (potentially the case for flow accounts in particular)[76].

[76] For example, trying to force tabular data (e.g. on the number of recreational visits to Melbourne's urban parks) into a level of spatial disaggregation for which it was not collected can lead to issues of reliability. Yet excluding that data from an account would mean a loss of valuable information that can provide insights for decision makers.

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DELWP (2016) accounts for Port Phillip Bay suggest that comprehensive accounts require *all* information to be "spatially referenced" insofar as it can be directly or indirectly referenced to a location and hence linked to an ecosystem asset. This suggests that accounting information simply has to be justified as being representative of an area as opposed to geo-referenced to a specific location. This provides for a more flexible approach to account development that facilitates the use of localised data where it is available and aggregated information where it is not.

Other relevant data issues that were noted in the literature include the varying quality, scale and accuracy of the data compiled for environmental-economic accounting created a barrier to account development as it meant refinement, reclassification, and projection of data was required (Sousa et al., 2016). This is particularly relevant where the data is spatially referenced over different time periods as this can require projection to the same co-ordinate system and refinement for consistency (e.g. spatial data from different years and with different spatial resolutions may need to be combined in order to fill the spatial gaps in mapping an area).

Some of the reviewed assessments do not attempt to quantify or monetise ecosystem service provision at all, but rather use qualitative information to score assets within a certain geographic area according to their importance for different ecosystem services using expert opinion. For example, a DELWP working paper (unpublished, 2016) "Valuing the benefits provided by Port Phillip Bay" adopted a qualitative approach to assess if the quantity of ecosystem services in Port Phillip Bay is expected to increase, decrease or remain the same in 2050 under a given future management scenario, compared to a do nothing scenario. This may have been relevant because of very poor data availability at the scale of interest, a lack of modelling capacity and/or time and resource constraints which meant it was inappropriate to attempt to quantify and monetise ecosystem service provision.

The data used do not necessarily have to be mutually exclusive but rather offer a range of different ways to describe and explain the status and productive capacity of natural assets within an urban area. For example, a given geographic area might be explained by the following, each of which provides some information on the likely scope of ecosystem services being delivered by that area and potential for policy / management responses:

- **Land cover:** grass;
- **Land use:** open space, public garden;
- **Ownership**: local government.

The proposed approach for the Melbourne account is to adopt a mix of spatially specific, tabular, qualitative and quantitative information in order to develop a picture of the status and productivity of ecosystem assets within the urban area. There are potentially a number of data sources that could be used to develop the Melbourne accounts. The selected sources will be chosen on the basis of how well the data would enable the development of up-to-date environmental-economic accounts for Melbourne in line with SEEA (UN, 2012). Specifically, the following will be considered when selecting data sources:

- **Date:** it is preferable for information to be as current as possible and for a single year. However, due to data constraints, it is likely that a range of data sources will be drawn on from different time periods and therefore that the figures will approximate status and productivity of assets over a certain period (e.g. 2015 to 2020). For example, the spatial information compiled in DELWP (2016) to estimate ecosystem extent in Port Phillip Bay was derived from different studies using different methods over the last 15 years, rather than a single point in time. Similarly, the best available data was used in developing the account for Victorian Parks network from a range of dates (DELWP and PV, 2015).

  This differs from the approach taken in national accounts whereby data is adjusted or assumed to pertain to a single year. Whilst it is understood that presenting data across a range of years is not good accounting practice, the primary aim for the urban Melbourne EEA is not to produce statistics (as developed by statistical agencies for national accounts) but rather to inform policy development. This means that a more pragmatic approach is

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being taken compared to the accounting / statistical rigour and standardisation required by SEEA-EA. To limit the scope of accounts to where data can be provided could limit the scope of the account and therefore its use for informing policy decisions. To adjust / assume data is representative of a given year is also not as transparent as presenting information for the year it was collected and risks errors. Instead, all relevant data will be included and deficiencies in the evidence base (including but not limited to the date of information) will be clearly articulated with a view to informing future data collection.

- **Type:** quantitative information is preferable to qualitative information**;**

- **Format**: ideally, we want information that is spatially explicit for use in GIS as it enables a more comprehensive understanding of status and productivity of assets and a more thorough analysis using the information compiled in accounts, including the assessment of trade-offs. However, if spatial information is not available then tabular information (i.e. from reports) could still be useful and relevant. In some cases, information may have some spatial referencing, for example the DELWP (2016) study of Port Phillip Bay used water quality information (dissolved oxygen data) for eight discrete points around the Bay. Whilst this cannot provide a comprehensive account of water quality across the Bay, it is still useful to understand water quality in different parts of the Bay and (where time series data is available) how this changes over time. Also the mapping of some ecosystem services needs to be carefully considered due to their nature, for example Sousa et al (2016) note how a significant number of cultural services *can* be geometrically represented by points which reflect locations that allow a better experience (e.g. recreational visits, birdwatching), but in reality it is the seascape and landscape characteristics / birds' abundance and diversity that provide the ecosystem service.

- **Resolution:** if several spatial datasets have been identified, then resolution of that data might be an important factor in deciding which one to choose for developing the account. The highest resolution data is not always the preferred choice as the time required to process analysis using such data may be significant whilst the added value in terms of improved insights/understanding of the status or productivity of ecosystem assets may be minimal.

- **Geographic area**: the urban area to be assessed will be unique and therefore the ideal dataset is one that is spatial (where relevant) and covers all of Victoria because this can be cut to different geographic areas. However, this may not be the case for all datasets. Careful judgement has to be given as to if and when it is appropriate to take data / value / estimates from one region (within Victoria or potentially including regions outside of Victoria) and apply within the assessment boundary, consulting with relevant economic valuation guidelines on benefit / value transfer.

- **Temporal coverage**: having datasets that record changes over time in a consistent manner is useful for tracking and reporting trends and exploring relationships between these trends and causative factors. As noted in DELWP (2016) accounts will ideally have an opening and closing balance and show change in assets and ecosystem services over time, providing information for government reporting, investment and program evaluation and forward looking decision-making. Where time series data is not available, the accounts will represent a snapshot of the status and productivity of ecosystem assets. The ABS note that "point in time" case studies are not as valuable to policy and decision making as accounts that are built up using long time series data (Clark, 2019).

Recommendations for refining the approach to deliver spatially explicit accounts will be outlined where appropriate.

A7.2. Uncertainty assessment and sensitivity analysis

The urban Melbourne EEA will report a single estimate of ecosystem service provision (i.e., *physical* provision) as opposed to a range, as per SEEA guidance. However, where possible and useful, a range of monetary valuation approaches (e.g., welfare and exchange values) will be taken and this range will be reported in the *monetary* account. Uncertainty will be summarised by using scores of 1 (low), 2 (medium) and 3 (high) for (a) data sources and (b) methodological assumptions. These scores will be combined through multiplication to estimate an overall uncertainty score considering the confidence in the underlying data and key assumptions made, see Table A7.1. The overall (i.e. combined) uncertainty ratings and scores are as follows:

- Low uncertainty = 1 to 2 *(high confidence)*
- Medium uncertainty = 3 to 4 *(medium confidence)*
- High uncertainty = 6 to 9 *(low confidence)*

Table A7.1. Approach to assessing uncertainty

		Evidence (score)		
		Low (1)	**Medium (2)**	**High (3)**
Assumptions (score)	**Low (1)**	1	2	3
	Medium (2)	2	4	6
	High (3)	3	6	9

A7.3. Measurement baseline

Ecosystem service measurement baselines (also referred to as counterfactuals) are needed in environmental-economic accounting to ensure consistent quantification of ecosystem service flows in different contexts and are implicitly set at zero (i.e. no ecosystem service provided) (SEEA-EEA, 2020a).

Whilst all of the reviewed studies acknowledge that environmental-economic accounts report the "total" (not marginal[77]) provision of ecosystem services by environmental assets, many imply a "no ecosystem asset (natural capital)" is adopted without explicitly stating what this is. Assessing total value requires a measurement baseline to be established (i.e. what would be there in the absence of the natural environment). In developing the urban environmental-economic account in the UK, eftec (2017) discuss these potential measurement baselines as:

a) *Another type of natural capital. However, this would estimate the net ecosystem service provision and not the total level of provision because some level of ecosystem service provision would be delivered by the alternative land use;*
b) *No natural capital (i.e. a "concrete" baseline). While this is not realistic, it is the only baseline to give us the total provision of ecosystem services of the current natural capital. It also makes it easier for estimating some ecosystem services (e.g. carbon sequestration) as concrete would not provide them. For other services, however, further thought is needed: for example, a concrete baseline has some absorption capacity for different pollutants;*

[77] Marginal changes in outcomes refer to incremental (small) changes from the current situation and is typically what is estimated for policy appraisals. For example, a policy may seek to improve (for example) water quality from its current status towards good ecological condition by investing in ecosystem assets (e.g. wetlands). By contrast, environmental-economic accounts seek to estimate the effect of removing all existing ecosystem assets (e.g. wetlands) that affect water quality (for example) to estimate the total value of these assets.

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The Valuing Victoria Parks DELWP and PV (2015) account explicitly states that the measurement baseline is "the absence of parks" but the definition of what this constitutes varies throughout. For many ecosystem services an explicit definition of what a no natural capital (ecosystem) measurement baseline looks like is not needed as total provision can simply be assumed to be zero. For example, no visitors to the natural environment and no carbon storage or sequestration. Interestingly, DELWP and PV (2015) do explicitly state the measurement baseline for coastal erosion as the absence of parks as a management designation, resulting in coastal wetland being cleared or degraded to a point where there would be zero protection against storm surge events, sea inundation or coastal erosion (and therefore built infrastructure would be required).

Whilst this explicit explanation of the measurement baseline for coastal erosion is not necessarily required (as a zero protection could be assumed in the absence of ecosystem assets), the measurement baseline has to be explicitly stated for other ecosystem services. For example, flood risk is a relative metric, meaning that the risk under the measurement baseline cannot be assumed to be zero (as that would imply clearing all natural capital (ecosystem assets) is a good thing) and needs to be measured relative to the current level of risk. DELWP and PV (2015) adopt an "urban residential development" measurement baseline for flood risk as recommended by eftec (2017) for UK accounts.

Interestingly, for water filtration and purification, DELWP and PV (2015) adopt a different measurement baseline based on the type of park being assessed. For non-metro parks the relevant measurement baseline was assumed to be grazing (agricultural) land use, where for metro parks the relevant measurement baseline was urban land use. Both are attempts to capture the total provision of the ecosystem service based on the most likely alternative "non-natural" land use (agricultural land can be justified as "non-natural" for use as a measurement baseline on the basis that it is of relatively low ecological functioning compared to (for example) wetland, forest etc. However, this remains a marginal or net estimate as there will be some level of ecosystem service provision from agricultural land).

Some studies estimate the marginal change in ecosystem service provision under different management scenarios. Whilst useful from a policy/management perspective, this marginal approach is not considered to be consistent with ecosystem focus on total contribution of the environment to society and the economy

The SEEA-EEA (2020a) guidance suggests the use of bare land where an explicit measurement baseline is needed, although it is recognised that this may not be considered to be conceptually strong, may be counterintuitive in certain cases (e.g. where bare land provides some level of ecosystem service) or cannot be modelled. Therefore, the recommendation is to differentiate in a systematic way, between ecosystem services for which the baseline is bare land and services for which the baseline is zero service supply. Clear communication and explanation of the chosen methods is required. A "no ecosystem asset" baseline is proposed for use in the Melbourne assessment as per SEEA-EEA guidance and the UK urban accounts because it is the only baseline to give us the total provision of ecosystem services of current ecosystem assets. The specific measurement baseline adopted will be defined appropriately for each ecosystem service with an accompanying explanation provided.

A7.4. Assessment year

The year for which an economic assessment is developed depends primarily on data availability. Because the underlying datasets for the urban Melbourne EEA are drawn from multiple years, the account can be more accurately described as an assessment for a given period (e.g. 2015 to 2019) rather than a specific year (e.g. 2019). This was the case for the DELWP (2016) Port Phillip Bay study which drew evidence from a 15-year period. It is a more pragmatic approach to that taken in national accounts whereby data is adjusted or assumed to pertain to a single year.

Where necessary, assumptions are made to combine data from multiple years in a way that relates to a given year (i.e. 2019), although the year of the underlying source and data is still made clear. For example, estimates of the

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relationship between an ecosystem and its production of an ecosystem service may be from academic research undertaken in 2014 and an assumption is adopted that this relationship is stable and therefore relevant to apply to an analysis that is being developed for 2019.

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Annex 8. Classifying and mapping urban ecosystem asset extent

Once the environmental-economic accounting area and urban ecosystem assets are defined (see Section 2.3 and 2.4 respectively), it is necessary to classify urban ecosystem assets so they can be consistently organised within the environmental-economic accounting framework over time. There was no classification of urban ecosystem assets in the literature reviewed. Instead, the description of specific natural environmental assets in the urban context varied across the literature, as follows:

- Most of the reviewed assessments focus on broad habitat types within the geographic boundary, such as woodland, grassland, parks, and wetlands. SEEA refers to these broad habitats as "ecosystem types". Some assessments are also quite specific in the types of habitats included, such as broadleaf, coniferous and wet woodland, whereas others are ambiguously labelled as "open" or "green" spaces. These different classifications of ecosystem assets are not necessarily mutually exclusive and are often subsets of each other (see Table A9.1).

- Some of the reviewed assessments focus on specific green and blue features, such as street trees and rivers and some include ecosystem assets that have been integrated into the built environment, such as green roofs and walls.

- Built infrastructure (e.g. built-up area, roads) is included within the habitat type classifications which means that 100 per cent of the land within the defined urban area is accounted for, which may be useful for decision making when considering green-to-built infrastructure ratios (for example).

Table A8.1. compiles the specific ecosystem type descriptions from the global assessments that were reviewed. The scope of ecosystem assets included within a specific account varies depending on the location (i.e. some urban areas are near the coast or forest etc.) and by data availability.

Table A8.1. Ecosystem descriptions used within urban assessments globally

Broad ecosystem type	Specific ecosystem type	
Heathland/Scrub	• Dense scrub	• Heath or moor
Woodland/Forest	• Urban woodland • Woodland scrub • Broadleaf woodland	• Coniferous woodland • Wet woodland
Wetland	• Wetlands • Reedbeds • Bog	• Swamp • Riparian zones
Freshwater	• Urban rivers • Water body • Water margin • Rivers and streams • Standing water • Bodies of water • Running water	• Open water • Water • River and streams • Lakes • Rivers • Freshwater systems • Rivers and canals including banks
Coastal margin	• Urban area on coastal margins • Beach	• Cliff and talus

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Broad ecosystem type	Specific ecosystem type	
Grassland	• Grassland • Amenity grassland • Neutral grassland • Improved grassland • Seminatural grassland • Neutral unimproved grassland	• Marshy grassland • Lowland meadow • Semi-improved grassland • Improved grassland • Prairies • Alvar (sparse grassland vegetation)
Agriculture	• Orchard • Croplands • Rangeland • Allotments • Community gardens	• Enclosed farmland • Arable • Pastures • City farms
Trees	• Street trees • Isolated trees	• City trees • Hedgerows
Parks/Parkland	• Open space • Parks and sports • Country and regional parks	• Green spaces • Park and recreation system • Urban parks
Built green infrastructure	• Green roofs • Green walls • Green facades • Road verges • Housing greenspace • Village greens • Vegetated sustainable urban drainage systems	• Gardens • Communal gardens • Private gardens • Domestic gardens • Urban commons • Cemeteries • Churchyards
Built infrastructure	• Built-up areas • Roads • Road and rail corridors • Pedestrian paths	• Undeveloped land • Wasteland and disturbed ground • Cycling routes • Rights of way

In addition to variation in the description of specific urban ecosystem assets set out in Table A8.1., the literature reviewed also used a range of terms used to refer broadly to the natural environment within urban areas, such as natural capital, urban vegetation, and green and blue infrastructure.

Table 8.2. shows the mapping of VLCTS land cover categories to the broad ecosystem asset classification in a comprehensive and mutually exclusive way insofar as the entire land area within the region is captured under both classifications and the area within the VLCTS classification maps completely across to the broad ecosystem assets.

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Table A8.2. Broad assets mapped to VLCTS land cover classes (and other datasets) (DELWP, 2020)

Broad assets	VLCTS land cover class (and other datasets)
Marine	Water
Alpine	n.a.
Shrubland	Native shrubland
	Natural low cover
Grassland	Native pasture / grassland
	Horticulture / irrigated pastures and crops
	Dryland cropping
	Exotic pasture / grassland
Forest / woodland	Treed native vegetation
	Scattered native trees
	Hardwood plantation
	Conifer plantation
	Other exotic tree cover
Coastal margins	Saltmarsh vegetation
	Mangrove vegetation
	Natural low cover[a]
	Water[b]
	Estuary[c]
Farmland	*VLUIS (LU5)*[d]
Freshwater and wetland	Wetland – perennial
	Wetland – seasonal
	Water
Urban	Built environment
	Urban area
	Disturbed ground

[a] Natural low cover designated as Shrubland unless centroid falls within 100m of coastline (using 100m buffer from outer boundary of Vicgov region https://discover.data.vic.gov.au/dataset/victorian-government-regional-departmental-boundaries-vicmap-admin) – *Coastal margins*.
[b] Water designated as Marine unless centroid falls within 100m of coastline (as above) – *Coastal margins*; or terrestrially beyond 100m of coastline (as above) – *Freshwater and wetlands*.
[c] Where any centroid falls within Estuary layer (https://discover.data.vic.gov.au/dataset/estuaries) – *Coastal margins.*
[d] Where any Grassland centroid falls within LU5 class from VLUIS (https://discover.data.vic.gov.au/dataset/victorian-land-use-information-system-2016-2017) – *Farmland.*

Table A8.3. is a non-exhaustive summary of datasets that have been identified as being of potential relevance to mapping urban ecosystem asset extent for the Melbourne EEA based on the urban ecosystem asset classification presented in Table 3.1.2 in Section 3 in the main report.

Table A8.3. Extent assessment - non-exhaustive list of potential metrics and data sources

Data	Description	Metric	Type	Geographic Scope	Source	Year
Broad ecosystem extent	Broad habitats	Ha	Spatial	Victoria	DELWP (2018) Ecological Vegetation Classes	2005
		Ha	Spatial	Victoria	DELWP (2020) Victorian Land Cover Time Series	2015 - 2019
		Ha	Spatial	Australia	DAWE (2018) National Vegetation Information System	2001
	Freshwaters (rivers, lakes)	Ha	Spatial	Victoria	DELWP (2014) VicMap Hydro	2014
		Ha	Spatial	Victoria	DELWP (2018) Estuaries	2014
	Marine	Ha	Spatial	Victoria	DELWP (2020) CoastKit Resources - Combined Biotope Classification Scheme	2020
	Grass cover / tree cover / bare ground	Ha	Spatial	Urban Melbourne	DELWP (2020), VicMap Urban Tree Cover	2020
		Ha	Spatial	Victoria	DELWP (2019) Forest Extent, Victorian Forest Monitoring Program	2013 & 2018
		Ha	Spatial	Greater Melbourne	DELWP et al. (2019) Mapping & analysis of veg., heat & land use	2014 & 2018
		%	Spatial	Metropolitan Melbourne (34 LGAs)	Jacobs et al. (2014) Benchmarking Australia's Urban Tree Canopy	2013
	Agricultural land	Ha	Tabular	Inner/Interface Melbourne	Deloitte (2016) The economic contribution of Melbourne's food bowl	2010-11
		No.	Spatial	Australia	Australian City Farms & Community Network (n.d.) Directory, Data and Mapping	n.d.
		Ha	Spatial	Victoria	VLUIS mapping (2017) Victorian Landuse Mapping System	2015 - 2017
Built-up area extent	Impermeable surface	Ha	Tabular	W & N suburbs Melbourne	University of Melbourne (2019) From little things: More than a third…	TBC
		%	Spatial	Metropolitan Melbourne (34 LGAs)	Jacobs et al. (2014) Benchmarking Australia's Urban Tree Canopy	2013
		Ha	Spatial	Greater Melbourne	Melbourne Water/DELWP (2017) Melbourne Urbanisation Mapping	2011 - 2051
		Ha	Spatial	Victoria	DELWP (2020) Coordinated Imagery Program, various remotely sensed datasets with potential to spilt natural / artificial.	2017 - 2020
Integrated GBI extent	Green roofs	Ha	Tabular	City of Melbourne	GHD (2015) Rooftop Adaptation Study	n.d.
		Ha	Spatial	City of Melbourne	City of Melbourne (2015) The Rooftop Project	2015
	Green roof potential	Ha	Spatial	City of Melbourne	City of Melbourne (2015) The Rooftop Project	2015
		Ha	Tabular	City of Melbourne	City of Melbourne (2019) Valuing Green Guide Green Roofs, Walls…	n.d
	Tree and shrub cover	Ha	Spatial	Metropolitan Melbourne (34 LGAs)	DELWP et al. (2019) Mapping & analysis of veg., heat & land use	2014-18
		%	Spatial	Metropolitan Melbourne (34 LGAs)	Jacobs et al. (2014) Benchmarking Australia's Urban Tree Canopy	2013
	Canopy cover	% area	Tabular	Urban metro Melbourne	The Nature Conservancy & Resilient Melbourne (2019) Living Melb	n.d.
		Ha	Spatial	Urban Melbourne	DELWP (2020) VicMap Urban Tree Cover	2020
	Street trees	No.	Spatial	City of Melbourne/Manningham LGA	City of Melbourne (2016) Urban Forest Visual	2016
		Ha	Spatial	Urban Melbourne	DELWP (2020) VicMap Urban Tree Cover	2020
		No.	Tabular	City of Melbourne	Uni. Of Melbourne et al (2020) Patterns of tree removal and canopy…	2018
	Park trees	No.	Tabular	City of Melbourne	Uni. Of Melbourne et al (2020) Patterns of tree removal and canopy…	2018
Highly managed asset extent	Open space	Ha	Spatial	Metropolitan Melbourne	VPA (2016) Metropolitan Open Space Network	2016
	Private gardens	% area	Tabular	W & N suburbs Melbourne	University of Melbourne (2019) From little things: More than a third…	TBC
		Ha	Spatial	Metropolitan Melbourne (34 LGAs)	DELWP et al (2019) Mapping & analysis of veg., heat & land use	2014-18
	Public green space	% area	Tabular	W & N suburbs Melbourne	University of Melbourne (2019) From little things: More than a third…	TBC
		Ha	Spatial	Metropolitan Melbourne (34 LGAs)	VPA (2016) Metropolitan Open Space Network	2016
	Road verges	% area	Tabular	W & N suburbs Melbourne	University of Melbourne (2019) From little things: More than a third…	TBC
		Ha	Spatial	Metropolitan Melbourne (34 LGAs)	DELWP et al (2019) Mapping & analysis of veg., heat & land use	2014-18
	Community gardens	No.	Tabular	Victoria	Australian City Farms & Community Gardens Network	n.d.
	Public gardens	Ha	Spatial	Metropolitan Melbourne (34 LGAs)	VPA (2016) Metropolitan Open Space Network	2016
	Parks	Ha	Spatial	Metropolitan Melbourne (34 LGAs)	VPA (2016) Metropolitan Open Space Network	2016
	Sports grounds	Ha	Spatial	Metropolitan Melbourne (34 LGAs)	VPA (2016) Metropolitan Open Space Network	2016

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Annex 9. Ecosystem asset condition

The key objective of the condition account is to monitor changes in the *capacity* of ecosystems to deliver ecosystem services (eftec et al, 2017). An ecosystem condition indicator must therefore relate to a specific ecosystem asset and reflect its capacity to function and provide services (DELWP, 2016). Ideally, indicators will be selected based on an evaluation of how changes in ecosystem structure and function affect service flows – commonly referred to as an ecological production function approach – whereby information about inputs (i.e. ecosystem condition) is used to estimate the production of outputs (i.e. ecosystem services) (Guerry et al, 2012).

In principle, a careful analysis of interlinkages between fundamental ecological processes and ecosystem service provision would allow the definition of critical characteristics of ecosystem assets that should form the basis for accounting (Mace, 2019). The choice of the most appropriate indicators to use in each account depends on those which are most related to delivery of services provided by that particular ecosystem (Defra & ONS, 2014). However, the complexity of the natural environment means that the link between the condition of ecosystems and the provision of services is not clearly established in the literature[78]. Whilst some biodiversity components or ecosystem processes are clearly fundamental to the provision of certain ecosystem services from particular ecosystems, it is harder to prioritise them[79].

Furthermore, the relationship between ecosystem condition and the provision of ecosystem service flows can be complex and non-linear. This means that changes in a particular condition indicator may not lead to a discernible change in service provision until a critical threshold point is reached, after which changes in condition lead to significant and potentially irreversible changes in service provision (AECOM, 2015).

Given the above constraints to identifying a set of key ecosystem condition indicators that underpin service provision, all of the accounts reviewed compile information on indicators as 'proxies' for the capacity of ecosystem assets to deliver services.

The metrics used to populate condition accounts can be single measures that are representative of ecosystem condition, a series of measures and/or composite condition scores. For example, the DELWP and PV (2015) study on Victoria's Parks used a series of composite indicators to capture the condition of park assets. The UK urban natural capital account (eftec et al, 2017) usefully included a table outline the links between specific condition metrics and the ecosystem services they support.

Table A9.1. is a non-exhaustive list of potential metrics and data sources that could be used to populate the condition account for the Melbourne-EEA.

[78] As noted in Mace (2019) "In practice, this (identifying critical natural capital assets to report on in a condition account) is more complicated than it might appear. First, the asset–benefit relationships are complicated, multi-dimensional, multi-scale, and non-linear. Hence any attempt to map assets to services rapidly becomes enormously complicated. Second, ecosystem services are usually analysed one at a time, yet there are always interactions between different services that are missed in simple stock-flow accounting for individual services."

[79] "For example, soil, water, nutrients, and crop plants are necessary for agricultural production. But we could never assert that genetic diversity did not matter at all for most benefits, or that soil, water, and nutrients are dispensable or replaceable" (Mace, 2019).

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Table A9.1. Condition assessment - non-exhaustive list of potential metrics and data sources for Melbourne-EEA

Condition category		Indicator	Metric	Type	Geographic Scope	Primary ecosystem service supported	Source	Year
Ecological condition - Broad ecosystems	Biodiversity	Native vegetation condition	Score 1 - 100	Spatial	Victoria	Various	DELWP (2017) NVR condition	2017
		Wetland condition	Score 1-10	Spatial	Victoria	Existence / option value	DELWP Index of wetland condition (IWCDMS)	2011
		Habitat extent/quality for threatened species	Score	TBC	Victoria	Existence / option value	ARI Integrated Biodiversity Values Model (IBVM)	TBC
		Insectivorous species	Abundance	TBC	TBC	Supporting (pests and disease)	*TBC – DELWP Biodiversity – habitat suitability for insectivorous species*	TBC
		Threatened flora	Classification	Spatial	Victoria	Various	DELWP (2019) NVR2017_Location	2017
		Threatened fauna	Classification	Spatial	Victoria	Various	DELWP (2020) Victorian Biodiversity Atlas	2020
		Apiary sites on public land	Location	Spatial	Victoria	Food	DELWP in DELWP (2019)	TBC
		Mature trees (>80years old) with hollows	Number	Spatial	City of Melbourne	Various	City of Melbourne (2019) Mapping habitat trees	2019
			Number	Spatial	SE Australia	Various	Royal Botanic Garden Sydney (n.d.) Hollows as Homes	n.d.
		Structural and functional connectivity	Index	Tabular	City of Melbourne	Various	Kirk et al (2018) Linking nature in the city	2018
		Proportion of natural areas	%	TBC	TBC	Various	Rutebuka et al (n.d.) Urban nature indicators and targets for City of Melbourne	n.d.
		Proportion of natural areas that are protected	%	TBC	TBC	Various		
		Proportion of natural areas that are "at risk"	%	TBC	TBC	Various		
		Loss of natural areas	Ha	TBC	TBC	Various		
		Proportion of area restored to good ecological functioning	%	TBC	TBC	Various		
		Proportion of invasive alien species (Plants)	%	TBC	TBC	Various		
		Urban Greenspace Integrity (UGI) Index	Index	TBC	TBC	Various		
		Native biodiversity in built-up areas (Birds)	Index	TBC	TBC	Various		
		Change in number of native species (Plants)	Number	TBC	TBC	Various		
		Change in number of native species (Birds)	Number	TBC	TBC	Various		
		Change in number of native species (Butterflies)	Number	TBC	TBC	Various		
	Water	Freshwater/wetland condition	Score 1- 50	Spatial	Victoria	Various	DELWP Index of stream condition	1999-10
		Quality (physio-chem) Dissolved O_2	MG/L or %	Point	Victoria	Water ecosystem services	Environment Protection Authority and HydroNumerics	TBC
		Quality (physio-chem) Turbidity	NTU	Point	TBC	Water ecosystem services	Victorian Water Management Information System	TBC
		Quality (physio-chem) Conductivity	µS/cm	Point	Victoria	Water ecosystem services	Victorian Water Management Information System	TBC
		Quality (physio-chem) pH	pH	TBC	Victoria	Water ecosystem services	*TBC from OCES Marine and Coastal indicators*	TBC
		Quality (toxicants)	TBC	TBC	TBC	Water ecosystem services	*TBC from OCES Marine and Coastal indicators*	TBC
		Quality - Denitrification efficiency	Kilogram N / m3	TBC	TBC	Water ecosystem services	*TBC from OCES Marine and Coastal indicators*	TBC
		Quality - Estuaries	Score	Spatial	TBC	Water ecosystem services	DELWP Index of estuary condition (IEC)	2017-20
		Phytoplankton	TBC	TBC	TBC	Water ecosystem services	*TBC from OCES Marine and Coastal indicators*	TBC
	Carbon	Carbon stock	tCO2e	Spatial	Victoria	Global climate regulation	DELWP (2019) Above Ground Biomass, Victorian Forest Monitoring Program	1980-17
	Atmosphere	Air quality	TBC	TBC	TBC	TBC	TBC	TBC
Ecological condition - Integrated GBI	Biodiversity	Green roofs - invertebrates	No.	Tabular	Melbourne (6 roofs)	Various	Murphy (2013) in City of Melb. (2019) Quantifying the benefits	TBC
		Tree height	No.	Tabular	Greater Melbourne	Various	DELWP et al (2019) Mapping & analysis of veg., heat & land use	2014-18
			Height	Spatial	Urban Melbourne	Various	DELWP (2020), VicMap Urban Tree Cover	2020
		Tree species diversity	No.	Spatial	City of Melbourne	Various	City of Melbourne (2016) Urban Forest Visual	2016
		Tree health indicator	No.	Spatial	City of Melbourne	Various	City of Melbourne (2016) Urban Forest Visual	2016
		Rooftop beehives	No.	Tabular	Melb. fringe & suburbs	Food	Melbourne City Rooftop Honey	2020
	Location	Canopy cover in high urban heat areas	% area	Tabular	Melbourne	Local climate regulation	DELWP Planning	TBC

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Socio-economic characteristics		Canopy cover in heat vulnerable pop. areas	% area	Tabular	Melbourne	Local climate regulation	DELWP Planning	TBC
		Veg. cover in areas of differing air quality	Ha	Tabular	Melbourne	Air quality regulation	DELWP using CSIRO/BoM/UNSW info on air quality	TBC
		Population with access to green space	% pop.	Tabular	Melbourne	Recreation	ABS quoted in Australia's 2016 State of Environment report	2011
			Various [a]	Tabular	Melbourne	Recreation	Australian Urban Observatory (2020) Public Open Space	2020
		Population with access to urban parks	No.	Tabular	Melbourne	Recreation	Parks Victoria in DELWP and Parks Victoria (n.d.) Valuing Vic. Parks	n.d.
		Natural assets in areas at risk of natural hazards	Ha by risk	TBC	TBC	Hazard regulation	TBC	TBC
		Light pollution	TBC	TBC	TBC	Various	*TBC from OCES Marine and Coastal indicators*	TBC
		Noise pollution	TBC	TBC	TBC	Various	TBC	TBC
		Proximity of habitats to urban area	Ha by proximity	Spatial	TBC	All	DELWP (2020) Land Cover Time Series	1987-2019
	Cultural assets	Cultural heritage sensitive sites	Ha	Spatial	Victoria	Cultural / spiritual wellbeing	Victorian Spatial Data Library / Victorian Heritage Register / Aboriginal Victoria / Parks Victoria	2020
	Built assets	Car parks	Ha	Spatial	Victoria	Recreation	LGA open space facilities	TBC
		Park benches	No.	Spatial	Victoria	Recreation	LGA open space facilities	TBC
		Park toilets	No	Spatial	Victoria	Recreation	LGA open space facilities	TBC
		Boating points	No.	Spatial	Victoria	Recreation	DJPR (2018) Boat Access Points	2018
			No.	Spatial	Victoria	Recreation	DJPR (2018) VIC_BOAT_MOORING_POINTS	2018
		Bicycle Paths	Km	Spatial	Victoria	Recreation	Dept. Trans. (2016) Principle bicycle network	2016
			Km	Spatial	Victoria	Recreation	DELWP, TR_ROAD	2020
		Waterway/boating zone	Type	Spatial	Victoria	Recreation	Transport Safety Victoria (2015) Victorian Waterway Boating Zone Data	
		Walking	Km	Spatial	Victoria	Recreation	DELWP, TR_ROAD	2020
			Ha	Spatial	Metropolitan Melbourne	Recreation	VPA (2016) Metropolitan Open Space Network, 400m Walkable Catchment	2016
		State Forest Recreation assets	No.	Spatial	Victoria	Recreation	DELWP (2020), RECWEB_ASSET	2020
		Visitor Facilities	No./Condition	Tabular	Victoria	Recreation and tourism	Parks Victoria	
	Governance and management practices	Pastoral agriculture	Ha	Spatial	Victoria	Biomass - Food	VLUIS mapping (2017) Victorian Landuse Mapping System	2015 - 2017
		Arable agriculture	Ha	Spatial	Victoria	Biomass - Food	VLUIS mapping (2017) Victorian Landuse Mapping System	2015 - 2017
		Mixed use forest	Ha	Spatial	Victoria	Various	DELWP (2019) Forest Extent, Victorian Forest Monitoring Program	2013 & 2018
		Plantation forest	Ha	Spatial	Victoria	Biomass - timber	DELWP (2019) Forest Extent, Victorian Forest Monitoring Program	2013 & 2018
		Ramsar wetland designation	Ha	Spatial	Victoria	Various	DELWP (2019) Ramsar Wetland Areas	2019
		National park designation	Ha	Spatial	Victoria	Various	DELWP (2020) Public Land Management	2020
		Nature Conservation Reserves	Ha	Spatial	Victoria	Various	DELWP (2020) Public Land Management	2020
		Conservation status	Ha by condition	Spatial	Victoria	Various	DELWP – EVC dataset, BCS field	Current

[a] The Australian Urban Observatory has information on access to public open space including (a) % of dwellings within 400 m or less of a local park (> 0.4 to. <= 1 ha) (b) % of dwellings within 800 m of less of a neighbourhood park (>1 ha to <= 5 ha) (c) % of dwellings within 400 m of less of a neighbourhood park (> 0.5 ha).

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Annex 10. Quantifying the physical provision of ecosystem services in urban Melbourne

Draft guidance on biophysical modelling for SEEA-EEA (Tomscha, 2019) outlines a tiered approach to developing accounts:

- Tier 1: relies on globally available datasets and pre-constructed ecosystem service models using freely available tools, requiring very little user input;
- Tier 2: models ecosystem services using national datasets, requiring some customisation and validation of ecosystem service models; and
- Tier 3: draws on the best available local data using bespoke models, parametrised for local contexts.

A Tier 3 SEEA-EEA is ideal for accuracy, however, rough estimates based on global models and global datasets are a first step towards locally parametrised models, and many organisations may choose to initiate SEEA-EEA using a Tier 1 approach (Tomscha, 2019).

Many of the methods adopted to quantify (and value) ecosystem service provision in the reviewed literature are bespoke based on the data and methods available within each country/region (i.e. Tier 3), although some of the reviewed studies adopt the publicly available biophysical models such as iTree (Tier 2) and InVEST (Tier 1).

Martínez-Harms and Balvanera (2012) reviewed methods used to estimate ecosystem service supply (i.e. physical provision) and concluded that the most frequently used method to estimate ecosystem service provision is the use of causal relationships (i.e. Tier 3) based on the understanding of ecosystem services and readily available information (e.g. dose-response functions where the provision of a service by an ecosystem asset varies according to the prevailing environmental conditions / status of the asset. For example, carbon sequestration rates are dependent upon the vegetation type and condition), with other methods including the extrapolation of primary data (e.g. field data, surveys, census data – especially relevant for recreational visits), expert knowledge, regression models and look-up tables.

The studies reviewed quantify (and value) ecosystem service provision for specific ecosystems where possible (this is mostly for regulating and provisioning services) and for the assessment area as a whole where it is not appropriate to attribute provision to specific ecosystems (mostly cultural services).

Physical quantification commonly focuses on measurement of ecosystem structures, processes and functions (i.e. the supply side of ecosystem service flows) but quantification of ecosystem contributions can also take place through a focus on the use of ecosystem services, for example the number of visits to a national park (SEEA-EEA, 2020a).

The physical metrics used to estimate ecosystem service provision in the reviewed assessments depend on the type of service as set out in Table A10.1. which shows:

- Provisioning services are measured through physical output such as kilograms of food;
- Regulating services are measured through reductions in environmental harm such as global climate change (measured through carbon capture and storage) and pollution of clean water (waste assimilation - removal of nutrient excess); and
- Cultural services are measured through number of interactions such as recreational visit numbers.

Unofficial

Table A10.1. Example metrics for physical provision of ecosystem services

Ecosystem service		Measurement	Metric (per year)
Provisioning	Biomass - Food	Physical output	Kilogram
	Biomass - Timber	Timber harvest	Tonnes
	Biomass - Energy	Woodfuel harvested	Tonnes
	Water provision	Water runoff [a]	Ml
Regulating	Air quality regulation	Pollutant reduction	Tonnes or μ^3
	Water quality regulation	Wastewater discharge (Pollution assimilation)	Kilogram pollutant / m^3
	Flood risk regulation	Range of 100-year peak flows	m^3 / s
	Landslide regulation	Quantity soil loss	Tonnes
	Coastal protection	Length of coastal mangrove/saltmarsh/wetland	Kilometre
	Global climate regulation	Carbon sequestration and storage	tCO_2e
	Local climate regulation	Temperature differential	°C
	Storm water management	Avoided runoff	Gallons
	Noise regulation	Decibel differential	dBA
Cultural	Recreation	No. of interactions	Number
	Tourism	No. overnight stays	Number
	Aesthetic	No. photographs uploaded to internet Level of tranquillity Dark skies / Level of light pollution	Number Score Score
	Education and research	Educational visits / research permits Citizen science	Number
	Historic and contemporary cultural heritage	Visits to sites of post-contact cultural significance	Number
	Existence / Option value	Designated sites / charismatic species	Number
	Social cohesion/community	Volunteer time	FTE
Bundle	Amenity	No. households in proximity to parks	Number
Supporting	*Habitat provision*	*Habitat suitability*	*Score*
	Genetic diversity	*Rare and threatened species / habitat*	*Number / Ha*
	Nursery populations	*Enhancement of biomass*	*Tonnes*
	Pollination	*Apiary sites (Crop Pollination)*	*Number*
	Soil cycle regulation	*Soil health index*	*Score*
	Water cycle regulation	*Dissolved oxygen*	*Mg / L or % saturation*
	Nitrogen cycling	*Denitrification*	*Kilogram N / m^3*
	Pest and disease control	*Insectivorous birds and bats*	*No./diversity*

[a] The DELWP and PV (2015) study assessed runoff under the current park network and a measurement baseline scenario where parks are cleared for grazing (as a "without" natural capital scenario) to estimate water provision due to the existence of parks. Under this approach runoff (i.e. water lost outside of the parks area) was estimated to increase under the measurement baseline suggesting water provision (i.e. that retained within the parks) increases due to forests and wetlands. Whilst this approach is suitable as an indicative measure (with appropriate caveats), the freshwater runoff that moves outside of the parks area under the measurement baseline is not necessarily lost (e.g. to the ocean) and could still provide value to society. Whilst water provision has been estimated in some studies as a provisioning service on the basis that ecosystems retain water within a catchment (prior to flowing to sea), the UN (2019) notes that water is not the result of ecosystem processes and therefore water supply may be better categorised as an abiotic service. The study team suggests that further work is needed to be done to understand the ecosystem service associated with water provision and how it is to be assessed from a practical perspective. Therefore, it is excluded from quantification and valuation in this Melbourne EEA (although existing estimates of the physical amount and monetary value of water supply that were identified from the reviewed Victoria specific literature (see Annex 6) are noted for future reference / account development).

The physical assessments in the reviewed studies focus on final ecosystem services (e.g. crop yield) as well as intermediate or supporting ecosystem services (e.g. pollination which supports crops). Whilst estimating the physical (kilograms) and monetary reliance of final services (e.g. food production) on intermediate services (e.g. natural pollination) is both worthwhile and legitimate from an economic perspective, reporting its value *alongside* the (ecosystem asset resource rent) value of final services (e.g. crop production) in an environmental-economic account risks double counting (and therefore overstating) the value of ecosystem assets. Some of the supporting services that are defined in the literature (see Table A10.1.) such as biodiversity habitat will be captured as stock metrics in the asset extent and condition assessment.

Assessments also estimate the socio-economic impact of ecosystem service provision where this is necessary for monetary valuation. There is not a dedicated account within the SEEA guidance (UN et al, 2012), but this could be usefully reported as an additional flow account.[80] Such "socio-economic" impacts typically estimate the population affected by regulating services through metrics such as:

- Population exposed;
- Quality adjusted life years (QALY's);
- Change in morbidity incidence; and
- Change in mortality incidence.

The remaining sections of this Annex provide details on the studies that could be used to estimate the physical provision of the seven ecosystem services selected for inclusion within the urban Melbourne EEA.

A10.1. Air filtration

Table A10.2. provides details on the studies that could be used to develop a Melbourne specific assessment of the physical provision of the air quality regulating service provided by urban ecosystem assets and how the approaches and data from these studies are proposed for use to inform the Melbourne urban environmental-economic account.

The literature review found a range of different approaches to estimating the physical provision of air quality regulating service of vegetation are adopted globally. While the science is fairly robust, different models and different approaches may produce widely varying estimates of air pollution removal be ecosystems (eftec et al, 2017). There is a complexity to the service which makes estimating changes in pollutant levels challenging. There is a trade-off inherent between the accuracy of incorporating atmospheric transport and pollutant interactions at national scale, and the fine detail required to populate information about the type and location of vegetation on the ground (eftec et al, 2017).

[80] This point is mentioned in SEEA Environmental-economic accounting (SEEA EA) Final draft: 9.5.2 Methods for incorporating spatial variation in prices (pers. comm. Jonathan Khoo, ABS).

Unofficial

Table A10.2. Review of methods used to estimate the physical provision of air filtration from green and blue space within Melbourne

Source	Description	Used in Melbourne study?	
eftec (2017) A study to scope and develop urban natural capital accounts for the UK	The approach taken for the UK natural capital account (eftec et al, 2017) calculates the physical flow of air quality regulation using an atmospheric chemistry and transport model (called EMEP4UK) which generates pollutant concentrations directly from emissions, and dynamically calculates pollutant transport and deposition, taking into account meteorology and pollutant interactions. The role of vegetation in removing air pollutants is assessed using a comparison of a "with vegetation" and "without vegetation" scenario.	No	This study used atmospheric modelling that is specific to the UK and requires technical skills and experience to use.
AECOM (2015) Developing ecosystem accounts for protected areas in England and Scotland: Technical Appendix	This study adopts a static methodology where pollutants are considered in isolation, incorporating only limited effects of meteorology, and where effects of pollutant transport in the atmosphere as well as the feedback of the deposition on air concentration are not considered. Estimates of dry pollution deposition from trees are developed using the equation: ***Absorption = Flux * Surface * Period*** *Flux = deposition velocity * pollutant concentration* *Surface = area of land * surface area index* *Period = period of analysis * percentage dry days * percentage in-leaf days* This equation requires inputs such as deposition velocity, pollutant concentration, area of land, surface area index, period of analysis, proportion of dry days and proportion of 'in leaf' days. Deposition velocities used in this study were taken from Powe and Willis (2004) which were mostly based on US statistics (Nowak et al., 1998 and Broadmeadow and Freer-Smith, 1996).	No	This methodology applies US deposition velocities and would require a significant amount of work to estimate inputs into the absorption equation for Melbourne which is not considered to be a proportionate use of resources given the limitations of the approach.
Jayasooriya et al. (2017) Green infrastructure practices for improvement of urban air quality	This study uses a dry deposition model that is part of i-Tree Eco to quantify the air quality improvement benefits of green infrastructure for three different scenarios at the Brooklyn Industrial Precinct in Melbourne (an approximate land area of 262 hectares). The precinct is located in Brooklyn in the western suburbs of Melbourne, Victoria, less than 10 km from Melbourne's central business district. The precinct is triangular shaped and is bordered by Kororoit Creek, Geelong and Somerville Roads (Brooklyn Industrial Precinct, n.d). This study estimated a single tree would remove 0.0260 kgs of NO_2, 0.0084 kgs of SO_2, 0.0859 kgs of PM10, 0.0034 kgs of CO, 0.0027 kgs of PM2.5 and 0.0939 kgs of O_3 annually.[81] The i-Tree Eco is a peer reviewed open source software which was developed by the United States Forest Service. The study develops Melbourne specific parameters for input to the iTree Eco software by following the iTree Eco Users Manual (2014) and using the Australian compatible version of iTree Eco which was introduced in 2011 to include integrated air pollution and local weather data for Victoria.	Yes	The estimated pollutant capture figures per tree (kg/tree/year) will be used to provide an indicative estimate of the air quality regulating benefits of urban vegetation in Melbourne, noting the underlying limitations of iTree Eco and its application within Melbourne.
Jones, R. N. and Ooi, D. (2014) Living Brooklyn: Baseline Report on the Economics of the Urban Water Cycle in the Brooklyn Industrial Precinct in Melbourne.	This study calculated lost welfare for PM10 for people downwind of pollution from the Brooklyn Industrial Precinct (PM10 and PM2.5), west of Melbourne based on the benefit transfer of the US studies on welfare in this report's section on Health and Wellbeing. This was a point-source pollution problem where it was possible to isolate specific damage, with up to 18 daily exceedances of regulated limits of PM10 each year. For PM10, they calculated an annual range of \$0.16 to \$0.86 per m^2 health and welfare benefits based on deposition rates of 3 to 8 g per m^2 on trees. For PM2.5, direct health benefits were \$0.35 to \$2.89 for deposition rates of 0.13 to 0.36 g per m^2 per yr. The City of Melbourne (2019) report in which this study was found states that "Intensive green roofs and walls would be expected to capture half to most of the amount intercepted by trees and extensive green roofs and façades about one-third to one-half. Valuing the capture of other pollutants would increase these benefits." This information is not used to estimate air quality regulation by green roofs as it's not clear how it has been estimated and therefore how robust it is.	No	This study was not selected on the basis that it focused only on one geographic region within Melbourne, as opposed to providing a Melbourne wide estimate. Future work on the urban Melbourne EEA could use the estimating from this study to provide a range of values / sensitivity.
Fairman et al (2010) Using i-Tree STRATUM to estimate the benefits of street trees in Melbourne Victoria	This study uses a dry deposition model that is part of i-Tree Eco to quantify the air quality improvement benefits of green infrastructure in Melbourne but was undertaken prior to the Australian compatible version of iTree Eco being developed (see Jayasooriya et al., 2017). This study selected an appropriate 'US Climate Reference City' based on determining the similarity of a reference city and the subject city (Melbourne) in three elements: (i) tree species composition, (ii) number of heating degree days and cooling degree days, and (iii) annual precipitation. Berkeley in the Northern Californian Coast climate zone, was chosen as the most appropriate reference city for Melbourne.	No	Given the i-Tree Eco model has been updated to include data for Melbourne (see Jayasooriya et al., 2017) the methodology for estimating pollutant removal in this study is not considered further.

[81] These figures were drawn out of the Jayasooriya et al. (2017) study which reported that existing tree coverage of approximately 10 trees per hectare was estimated to remove 68kg of NO2, 22kg of SO2, 225kg of PM10, 9kg of CO, 7kg of PM2.5 and 246kg of O3 annually.

Unofficial

A10.2. Education

MJA (2016) estimate there were 2.5 million nature-based educational participation days by Victorian schoolchildren in 2014, consisting of approximately 1.5 million daytrips and 1 million overnight trips. School trip expenditure in Victoria was estimated to be $225 million (adjusting for expenditure “leakage” on goods and services outside of Victoria) with $108 million in gross-value-added to the Victorian economy[82]. Whilst these figures do not represent the value of these educational trips, it provides an indication of the value of nature-based education in supporting the Victorian economy.

Table A10.3. provides details on the studies that were considered for use to develop a Melbourne specific assessment of the physical provision of educational services provided by urban ecosystem assets and how the approaches and data from these studies are proposed for use to inform the Melbourne urban environmental-economic account.

[82] The estimated GVA contribution consists of $71 million in profits, wages and rents (i.e. direct gross value-added), and $37 million in supply chain activity to generate nature-based outdoor activity goods and services (indirect gross value-added).

Unofficial

Table A10.3. Review of methods used to estimate the physical provision of education from ecosystem assets within Victoria

Source	Description	Used in Melbourne study?	
Marsden Jacob (2016), Victoria's nature-based outdoor economy	This study estimated 2.5 million nature-based educational participation days by Victorian schoolchildren in 2014, consisting of approximately 1.5 million daytrips and 1 million overnight trips. These figures were calculated using: The "Student Activity Locator" database of school excursions for both catholic and public schools. This was used to estimate of the number of school days that students spent in nature-based outdoor activities and where these days were spent. These participation rates were scaled up to include other private schools in proportion to school student numbers reported by the Victorian Department of Education and Training Number of Enrolments 2015. The analysis only included participation days that were clearly associated with nature based activities. The Australian Camps Association's "Prices and Occupancy Report 2012". This was used as a top-down estimate of the number of Victorian public and catholic school student days spent on camp.	Yes	The Victorian Department for Education and Training (DET) Student Activity Locator database will be used to estimate the number of school visits to the natural environment within the area of the urban Melbourne EEA assessment boundary.
DELWP and Parks Victoria (2015), Valuing Victoria's Parks: Accounting for ecosystems and valuing their benefits	The study states that 'on average 215 research permits are issued in parks every year and 183,000 people participate in parks related education programs every year' using Parks Victoria data.	No	Educational visit data to specific parks within the boundary does not exist. Data on the number of research permits was acquired from Parks Victoria and is noted as an area for future work.

Unofficial

A10.3. Biomass - Food

A 2016 study (Deloitte, 2016) used based on ABS data to estimate the value of agricultural production in Melbourne, it estimated that in 2010-11:

- 0.1 per cent of Victoria's commercial agricultural land was located within Inner Melbourne[83], creating a gross value add of $40m/year. Given the LGA's that are included within this definition of inner Melbourne (see footnote), the expectation is that most of this agricultural land and production would be within the "urban" definition that is proposed to be adopted within this study (i.e. that this is capturing urban farm production). This figure was used to sense-check the estimates produced for the value of agricultural production for this urban Melbourne EEA.

- 3 per cent of Victoria's commercial agricultural land was located within Interface Melbourne[84], creating a gross value add of $818m/year. Given the LGA's that are included within this definition of interface Melbourne, the expectation is that much of this agricultural land would be outside of the "urban" definition (i.e. would be "rural") that is proposed to be adopted within this study.

The above agricultural production estimates exclude food that is produced within Melbourne's community gardens, private gardens and rooftops (e.g. bee hives).

Table A10.4. provides details on the studies that were considered for use to develop a Melbourne specific assessment of the physical provision of biomass for food provided by urban ecosystem assets and how the approaches and data from these studies are proposed for use to inform the Melbourne urban environmental-economic account.

[83] Consisting of the following LGA's: Banyule, Bayside, Boroondara, Brimbank, Darebin, Frankston, Glen Eira, Greater Dandenong, Hobsons Bay, Kingston, Knox, Manningham, Maribyrnong, Maroondah, Melbourne, Monash, Moonee Valley, Moreland, Port Phillip, Stonnington, Whitehorse, Yarra.

[84] Consisting of the following LGA's: Cardinia, Casey, Hume, Melton, Mornington Peninsula, Nillumbik, Whittlesea, Wyndham, Yarra Ranges.

Unofficial

Table A10.4. Review of methods used to estimate the physical provision of recreation from urban ecosystems within Melbourne

Source	Description	Used in Melbourne study?	
ABS Agricultural Commodities, Australia, 2017-18	This dataset reports agricultural yields (in tonnes) at a Statistical Area Level 4 (SA4) classification	Yes	**Commercial production:** Use the ABS data at SA4 level to estimate production within the urban boundary of the assessment area using a justifiable rule.
Zainuddin & Mercer (2014) Domestic residential garden food production in Melbourne, Australia: a fine-grained analysis and pilot study	This pilot study documents measured output from private domestic gardens in Metropolitan Melbourne. The data documented includes plot size (in square metres) and total yield (in kilograms) for 15 households (plots) over different periods (typically between 2 – 3 months) over a year, covering all seasons between July 2012 and July 2013.	Yes	**Household production**: Can be used to estimate household food production in gardens. Application to community gardens is an uncertainty but deemed to be suitable for an indicative estimate (the study focused on private domestic gardens). Application to private domestic gardens in urban areas will require estimating the proportion of households that produce food and an estimate of the number of private domestic gardens, which is not information that is currently available and so this is an area for further research.
Melbourne City Rooftop Honey (2020) The Project	This Melbourne based project installs, maintains and cares for the honey bee by using a mix of conventional & natural beekeeping methods. Funds are raised from local business and individual sponsorship of hives which keeps them maintained and to keep rolling out beehives in Melbourne. A map of hives across Melbourne is available on the website so hives within the assessment boundary could potentially be identified - currently there are 25 hives in Melbourne CBD, with a total of 120 hives placed around the Melbourne fringe and suburbs. Average honey production (kilograms) from a typical hive can be estimated based on a literature review and consultation with Melbourne City Rooftop Honey and applied to the number of hives in operation across Melbourne.	No	**Honey production:** Whilst the number of hives operated by Melbourne City Rooftop Honey that are within the assessment boundary could be used to estimate total honey production a year, this would only be a very small value which would already be captured within the ABS statistics and is an underestimate of total honey production and so it is not deemed proportionate to assess for this urban Melbourne EEA. Further work is needed to identify all honey production across Melbourne, including private / non-commercial production. Bees also support biodiversity and the production of crops (food) through pollination, whilst this supporting function is not being assessed in this preliminary environmental-economic account it could be considered in future iterations of the account as a key metric on the “condition” of ecological stocks (which determine the capacity of the stock to produce ecosystem service flows).
Wise (2014) Grow your own. The potential value and impacts of residential and community food gardening. Policy Brief No. 59, The Australia Institute, Canberra.	This study estimates 57 per cent of Victorian households are producing food in private gardens based on a literature review, nearly 1,400 household surveys across Australia and interviews with experts and community gardeners. However, the robustness of this figure is not clear and if applied to Greater Melbourne would likely overstate actual private garden production as it includes households in Victoria as a whole and it is reasonable to expect regional households to be more likely to grow food than metropolitan households. The study also includes households growing food in containers or on a balcony which whilst not outside of the scope of an urban environmental-economic account, are not the focus of this study which is on garden production. The expected discrepancy in production yield between balcony/pot/container production and garden production (i.e. we’d expect garden production to be much higher) means the proportion of households adopting each practice would be needed for a justifiable total estimate of food production in Greater Melbourne to be produced (i.e. by applying estimated average kg produced across each practice).	No	Applying this estimate to Melbourne households would likely overstate actual private garden production in the urban area as it includes households in Victoria as a whole. More specific estimates on number of balconies/pots/containers used for food production in urban Melbourne, as well as yield, are needed and could be an area for further research.

Unofficial

A10.4. Global climate regulation

The definition and measurement of carbon related services in environmental-economic accounting is a complex and developing area (Edens et al, 2019). A definitive treatment of climate regulation services is yet to be determined under the United Nations System of Environmental-Accounting (SEEA) Experimental Environmental-economic accounting (EEA) revision. There are three distinct approaches to framing and measuring the climate regulation service:

i) **Gross carbon sequestration approach:** to measure and value the **gross** annual addition to carbon stocks within the urban Melbourne EEA region. That is, the removal of carbon from the atmosphere and storage in plant biomass as an ecological function. This approach was set out in the 2012 SEEA EEA guidance[85] and variations of it have been widely applied in environmental-economic accounting studies including in Victoria (DELWP, 2019 and Keith et al, 2017). Gross sequestration will always be positive, which is an important attribute for environmental-economic accounting, and aligns with the conceptualisation of other ecosystem services in that 'dis-services' or negative contributions from the ecosystem to society (such as carbon emissions) are excluded.[86] However, this means that the impact of disturbances can be poorly reflected in ecosystem service flows. For example, bushfires will have a wholly positive impact on gross sequestration, as only the accumulation of carbon through post-fire regrowth will be measured

ii) **Net carbon sequestration (or net ecosystem carbon balance) approach:** some studies have focused on net change in carbon stock annually (known as net ecosystem carbon balance or NECB) (Keith et al, 2017). NECB equates to all carbon sequestered by an ecosystem in a time period less all carbon emitted/removed, including carbon losses due to disturbances such as fire and harvesting. Net sequestration more fully captures the impact of disturbances such as bushfires, as carbon emissions will be netted off from carbon accumulated through regrowth. However, this means that ecosystem service flows can be negative in years where emissions exceed carbon accumulated through regrowth.

By focusing solely on additions and reductions to carbon stocks, both gross and net sequestration fail to capture the contribution ecosystems make by storing carbon over time. For example, mature forests will typically sequester less carbon than young or regenerating forests (net sequestration in mature forests can be close to zero) but they may hold large stocks of carbon. A distinct 'carbon storage' service that is additional to carbon sequestration has previously been conceptualised in environmental-economic accounting literature, [87] but an approach has not been agreed or widely applied. The limitations of the carbon sequestration approach, as well as concerns of double counting if aggregated with carbon storage, have informed the emergence of a new approach - carbon retention.

iii) **Carbon retention approach**: Under this approach, the ecosystem service is conceptualised as the retention of carbon in an ecosystem. That is, the *avoided* release of carbon.[88] Carbon retention is envisioned as the *only*

[85] United Nations 2014, *System of Environmental-Economic Accounting 2012: Experimental Ecosystem accounting*, United Nations, New York, pp 64-66.
[86] United Nations 2014, *System of Environmental-Economic Accounting 2012: Experimental Ecosystem accounting*, United Nations, New York, pp 48-94.
[87] The 2012 SEEA EEA guidance outlines a distinct carbon storage service in addition to carbon sequestration. See: United Nations 2014, *System of Environmental-Economic Accounting 2012: Experimental Ecosystem accounting*, United Nations, New York, pp 64-66. A paper presented at the 25th meeting of the London Group on Environmental Accounting highlights the limitations of assessing carbon sequestration in isolation and proposes a distinct carbon storage service in addition to carbon sequestration. See: Keith, H, Vardon, M, Lindenmayer, D, Mackey, B 2019, 'Accounting for carbon stocks and flows: storage and sequestration are both ecosystem services', Paper for the 25th meeting of the London Group on Environmental Accounting, Melbourne.
[88] United Nations Statistics Division 2020, 'Chapter draft prepared for global consultation – Chapter 6: Ecosystem services concepts for accounting', System of Environmental-Economic Accounting 2012 – Experimental Ecosystem accounting Revisions, July, p. 16.

Unofficial

climate regulation service. Carbon sequestration is not a service in and of itself, but the supply of carbon retention services will increase as a result of positive net carbon sequestration.

Carbon retention can be quantified by measuring the stock of carbon in an ecosystem over an accounting period, which is as proxy indicator for ecosystem service flow.[89] If carbon stocks increase over time, then the quantity of carbon retention service supplied will have increased, and vice versa. The minimum carbon retention service that can be supplied is zero, when the stock of carbon is zero. Carbon dense ecosystems (such as forests) will supply greater carbon retention services compared to less carbon dense ecosystems (such as grasslands).

The impact of major disturbances is reflected in ecosystem service flows. For example, bushfires will reduce supply of carbon retention services as carbon stocks decrease, but ecosystem service flows will be positive as fire-affected forests still hold stocks of carbon. In fire-tolerant forests, ecosystem service flows will increase over time as vegetation regenerates and carbon stocks increase.

Table A10.5. provides details on the studies that could be used to develop a Melbourne specific assessment and how the approaches and data from these studies are proposed for use to inform the Melbourne urban environmental-economic account.

[89] This use of a stock measure to quantify service flow is analogous to quantifying the services supplied by a storage company in terms of the volume of goods stored (for example). For further discussion see United Nations Statistics Division 2020, 'Chapter draft prepared for global consultation – Chapter 6: Ecosystem services concepts for accounting', System of Environmental-Economic Accounting 2012 – Experimental Ecosystem accounting Revisions, July, pp 16-17.

Unofficial

Table A10.5. Review of methods used to estimate the physical provision of global climate regulation from green and blue space within Melbourne

Source	Description	Used in Melbourne study?	
Carnell et al (2016) Carbon sequestration by Victorian inland wetlands. Blue Carbon Lab, Deakin University, Victoria, Australia.	**Carbon sequestration (gross):** This study surveyed Victoria's inland wetlands for their carbon sequestration capacity and estimated average rate of 6.93 tonnes CO_2e / ha / year.	Yes	**Inland wetland:** Estimates of tonnes of carbon sequestered for wetlands within urban Melbourne will use this single estimate from the Carnell et al (2016) study in order to provide an indicative value. Further research is needed if habitat specific estimates of carbon sequestration are to be incorporated into the urban Melbourne EEA.
DISER FullCAM modelling data	**Carbon retention:** The Full Carbon Accounting Model (FullCAM) is a calculation tool for modelling Australia's greenhouse gas emissions from the land sector. Carbon dioxide removed from the atmosphere by forests, croplands, grasslands and other vegetation can offset emissions from farming and land clearing. Given the size of Australia's land sector is approximately 769 million hectares, it's impractical to measure emissions and abatement using just direct estimation methods, such as field sampling. Australia's national inventory system for the land sector relies on the use of a modelling framework. FullCAM estimates the carbon stock change in ecosystems including: - Above and below ground biomass; - Standing and decomposing debris; Soil carbon resulting from land use and management activities.	Yes	**All terrestrial ecosystem assets:** this approach would provide estimates of carbon retention services provided by all ecosystem assets within Melbourne. The extent to which this will capture narrow assets (e.g. street trees etc) needs to be confirmed with DISER.
DELWP and Parks Victoria (2015), Valuing Victoria's Parks: Accounting for ecosystems and valuing their benefits	**Carbon sequestration (gross):** This study estimates the carbon sequestered as a result of (a) parks revegetation programs using a value of **2 tonnes of carbon per hectare per year** (not CO_2e) as a conservative estimate based on an uncited reference to a study which estimates the carbon sequestration rate of revegetation sites in the dryland regions of South Australia of 7.6 CO_2-e t/ha/year and (b) forest revegetation program using a value of **5 tonnes of carbon per hectare per year** (not CO_2e) based on estimates by Greenfleet (a carbon offsetting provider, although further details of how this has been estimated are not provided).	Yes	**Parks and trees:** the estimate of tonnes of carbon sequestered per hectare for parks (2 tonnes of carbon per hectare per year) and trees (5 tonnes of carbon per hectare per year) will be considered for use to develop the urban environmental-economic account in Melbourne. Applying the quoted assumption in England et al (2006) of 456 trees per hectare, this works out as 0.011tonnes/tree/year or 11kg/tree/year.
DELWP (2016), Marine and Coastal Ecosystem Accounting: Port Phillip Bay	This study has used available data to produce a draft set of environmental-economic accounts for Port Phillip Bay. Sequestration rates for marine vegetation (e.g. seagrass) in the coastal and marine ecosystems in Port Phillip Bay are unknown. However, the study references estimates of carbon sequestration from the scientific literature which indicate a rate of up to 0.83 tonnes of carbon per hectare per year for seagrass (Port Phillip and Westernport Catchment Management Authority (2015). That study was also reviewed, and it also states carbon sequestration estimates from the literature for saltmarsh of 1.51 tonnes of carbon per hectare per year and mangroves of 1.39 tonnes of carbon per hectare per year).	No	The coastal margin is not expected to be a significant part of the urban Melbourne environmental-economic account. Furthermore, this study does not identify Victoria specific estimates of carbon sequestration. However, the estimates of tonnes of carbon sequestered per hectare for seagrass (0.83 tonnes of carbon per hectare per year), mangroves (1.39 tonnes of carbon per hectare per year) and (1.51 tonnes of carbon per hectare per year) could be considered for inclusion in the future if the underlying studies are deemed to be suitable for application of these values to the Melbourne context and these assets exist within the urban area of the assessment boundary.
DELWP (2019), Ecosystem Services from Forests in Victoria: Assessment of Regional Forest Agreement Regions	This study measured the ecosystem service of carbon sequestration through annual gross additions to the carbon stock. The approach involves the use of Land FOR data on carbon stocks for above ground biomass (tonnes/ha) for 2008-2018 on public open space, along with (some currently unidentified) data on losses due to harvesting, fire and other sources. This means that the increase in the stock of carbon due to sequestration was measured separately to the impact (emissions) from disturbances such as harvesting, fires and the natural dynamics of the forest including dieback and storms and climatic factors such as drought. To isolate annual gross reductions in carbon stock and attribute these losses to bushfire or timber harvesting annual carbon stocks were subtracted from the proceeding year's carbon stock to produce a dataset of annual carbon change. Timber harvesting and fire history datasets for each corresponding year were then used to define carbon losses as either bushfire, harvesting or other.	No	**Trees:** this approach based on changes in carbon stocks (with attribution to different emission sources that are then deducted from the net change in carbon stock to get a gross figure for sequestration) would enable net and gross figures for carbon sequestration to be estimated. It was not adopted as it is dependent upon data for emission sources (fires, harvesting and other) from the stock of urban trees in Melbourne being available in a way that can be easily integrated with stock data.

England et al. (2006). Rates of carbon sequestration in environmental plantings in north-central Victoria	**Carbon sequestration (gross):** The original source cannot be found. However, this study was quoted in Mekala et al (2015) and is described as estimating "rates of carbon sequestration in environmental plantings in north-central Victoria (Australia) in the medium to low rainfall areas, carbon sequestered per ha of green space per year planted with trees is 2.52 tonnes [sic] /ha/annum (with a standard deviation of 1.06), assuming there are 456 trees per ha in the age range of 5–20 years, grown from tube-stock re-vegetation (England et al. 2006)". This suggests a per tree value of *478 tonnes/tree/year or 5.5kg/tree/year.	Yes	**Trees**: Although the original source has not been found, a study which aligns with that described by the same authors has been found (CSIRO and SCION, 2006). The per tree estimate of 5.5kg/tree/year of carbon sequestered or 0.0055tonnes/tree/year will be used as a lower bound. The Mekala (2015) study implies that this is an estimate of carbon sequestered in above ground biomass only (hence why it might be lower than the value in DELWP and Parks Victoria, 2015).
Fairman et al. (2010), Using iTree STRATUM to estimate the benefits of street trees in Melbourne, Victoria	The physical and economic benefits of street trees in a subset of suburbs in Melbourne, Victoria, were assessed in a proof-of-concept of iTree Streets: STRATUM (Street Tree Resource Analysis Tool for Urban Forest Managers), a street tree evaluating model developed by USDA Forest Service. The STRATUM model quantifies the physical amount of carbon sequestered in kilograms (as well as emissions from maintenance and decomposition of trees) and in Melbourne based on the selection of a reference city (Berkeley, Northern California) in the US with similar characteristics (tree species composition, temperature and precipitation) and a sample of 5-6% of street trees as well as information on management costs and general city information. Hume is estimated to have carbon sequestration rates of 31 tC/ha whereas Melbourne is estimates to have a value of 11 tC/ha.	No	The value is effectively based on a benefit transfer from the US by aligning Melbourne with a similar US city (Berkeley, Northern California) and running the model using the parameters of that city with some adjustment to the Melbourne context. The authors note that the model has been designed for the US, and thus the results are of value and of interest but are by no means necessarily precise for Australia. The recommendation is for a model of iTree Streets: STRATUM to be developed for Australia, using allometric equations, species lists, and cost and benefit prices designed exclusively for streets in Australia in order for a more rigorous and accurate estimation of the value of street trees in Melbourne.
Moore (2009) People, Trees, Landscapes and Climate Change	This report estimates carbon sequestered in street trees in Melbourne as a stock (rather than an annual flow). The figures used are unsubstantiated with no reference sources provided, but the logic is that there are at least 100,000 mature trees in the inner city area along and each weigh approximately 100 tonnes of which about 80% is water leaving about 20 tonnes of structural mass, of which about 50% or 10 tonnes is carbon. Thus (the report states), there is about a million tonnes of carbon sequestered (stored in the stock) in these inner city trees.	No	The report estimates carbon sequestered in street trees in Melbourne but as a stock, rather than an annual flow.

A10.5. Local climate regulation

The current total socio-economic costs of “extreme heat” in Melbourne (including heatwaves and single hot days over 30°C) are estimated to be significant. These costs include productivity losses to the economy from heatwaves in Melbourne ($53 million per year) and wider costs to the community from extreme temperatures in the City of Melbourne (CBD only) including additional hospital visits and deaths ($79 million per year), energy costs ($5.7 million per year), anti-social behaviour ($4.6 million per year), travel delays ($0.57 million per year), tree deaths ($1.8 million per year) and additional tree irrigation ($0.08 million per year). Table A10.6. shows that the costs of extreme heat are borne by all economic units including the government, communities and businesses.

Table A10.6. Current total estimated socio-economic costs of heat in Victoria

Impact	Heat type	Economic unit			Spatial area	Cost	Year[90]	Source
		Gov.	*Com.*	*Bus.*		***(2019)***		
Ill health	High temp	✓	✓	✓	City of Melb.	$79m/yr	Annual	AECOM (2012)
Productivity	Heatwaves			✓	Melbourne	$53m/yr	2018	NCEcon. (2018)
Energy costs	High temp	✓	✓	✓	City of Melb.	$5.7m/yr	Annual	AECOM (2012)
Assaults	High temp	✓	✓	✓	City of Melb.	$4.6m/yr	Annual	AECOM (2012)
Tree deaths	High temp	✓	✓		City of Melb.	$1.8m/yr	Annual	AECOM (2012)
Travel delay	High temp		✓	✓	City of Melb.	$0.57m/yr	Annual	AECOM (2012)
Tree irrigation	High temp	✓	✓		City of Melb.	$0.08m/yr	Annual	AECOM (2012)

The costs in Table A10.6. have **not** been aggregated to provide an indicative estimate of the total cost of heat in Melbourne because the costs to the economy (in terms of productivity) are only estimates for specific heatwave episodes (not all high temperatures) and the community impacts focus only on the City of Melbourne (not the wider Metropolitan area). There are also other values missing from Table A10.6. including avoided costs of road and pavement maintenance, avoided cost of artificial shading and avoided carbon emissions (AECOM, 2012; Victoria University, 2015). Aggregating these figures would therefore underestimate the total cost of high temperatures to Melbourne’s economy and society.

Table A10.7. provides details on the studies that were considered for use to develop a Melbourne specific assessment of the local climate regulating service provided by urban ecosystem assets and how the approaches and data from these studies are proposed for use to inform the Melbourne urban environmental-economic account.

[90] Annualised values have been calculated using an equivalent annual cost calculation for the present value of costs over the period 2012 to 2051 which have been estimated by AECOM (2012) using a 3% discount rate. This represents the “average” annual cost over the 40 year period, in reality the costs will increase over the period due to population growth and climate change.

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Table A10.7. Review of methods used to estimate the physical provision of local climate regulation from green and blue space within Melbourne

Source	Description	Used in Melbourne study?	
AECOM (2012) Economic assessment of the Urban Heat Island effect	Develops an evidence-based economic assessment of the current and future costs associated with heat, heatwaves, and the intensification of the Urban Heat Island in the City of Melbourne. Provides estimates of the link between temperature and different socio-economic outcomes in Melbourne (dose-response functions) including morbidity and mortality based on a published report from Department of Human Services (2009) on the health impacts of 2009 heat wave in metropolitan Melbourne, see Table 31.	Yes	**Effect of temperature on health outcomes (morbidity and mortality):** Estimate the effect of GBI on health outcomes by adopting the dose-response functions from this study which link different (air) temperatures to morbidity and mortality. (Requires estimates of changes in air temperatures due to GBI).
	Uncited reference in this document stating that *"Initial studies by City of Melbourne show that temperature directly underneath the canopy by 0.7 - 6.8 degrees"* which is an incoherent sentence but suggestive of evidence of significant cooling due to canopy cover within Melbourne.	No	The reference is uncited and incoherent, so it is not possible to determine to what the estimates are actually referring to. Furthermore, the higher end of the range is much higher than other estimates found in the literature.
Al-Gretawee et al. (2016) The cooling effect of a medium sized park on an urban environment.	Estimates the *maximum* cooling effect of a park in Melbourne on ambient temperature at 1.5 metres above the ground to be 4.3°C, that this was evident between 8am and 12pm and was estimated to extend out 860m from park boundaries. The study found minimal or no cooling at other times of the day. The study took place on May / June 2015 (autumn / winter), when ambient temperatures are not high.	Yes	**Effect of GBI on temperature (parks):** Although this study took place in autumn/winter when it might be expected that the temperature change due to parks might be different from spring/summer, it is currently the best source of information on the cooling effect of parks within Melbourne. The cooling effect of parks is an area for further research.
Chen et al (2014) Urban vegetation for reducing heat related mortality	The potential benefits of urban vegetation in reducing heat related mortality in Melbourne is investigated. The study considers various scenarios for increasing vegetation in Melbourne CBD.	No	The study focuses on large scale increases in vegetation extent rather than the current effect of existing vegetation.
City of Melbourne (2014) Urban forest strategy – Making a great city greener 2012-2032. Melbourne, Australia.	This City of Melbourne report quotes a US study (McPherson, 2009) which finds that the ambient temperature in a car park shaded by trees can be 2 degrees centigrade cooler than an equivalent unshaded car park.	No	Although quoted in a City of Melbourne report, the figure is from a US study and so it is not deemed to be as applicable as Melbourne specific estimates of the effect of street trees.
CRCWSC (2017) The climatic benefits of green infrastructure – Industry Note	This industry note provides estimates of the cooling effect of green infrastructure, specifically street trees, in Melbourne. It finds that a study of a single isolated tree in Melbourne cemetery on very hot days in 2014 the air temperature below the tree canopy was 0.6 to 1.2 degrees cooler than immediately upwind of the tree. It also states that during hot daytime conditions, the air temperature in a tree lined street was 0.2 to 0.9 degrees cooler than an equivalent tree with little canopy cover.	Yes	**Effect of GBI on temperature (street trees):** Use to estimate an average change in air temperature due to street trees in Melbourne by applying this estimate to the extent of trees within the urban area of the assessment boundary.
CRCWSC (2019) Estimating the economic benefits of Urban Heat Island mitigation – Economic analysis	Estimates the present value (50yrs) of socio-economic benefits due to urban heat island (UHI) mitigation (summertime cooling) in a new suburban development through landscape initiatives (urban greening and integrated water management) necessary to achieve significant reduction in the UHI effect in western Melbourne. The study adopts the temperature-morbidity relationships set out in AECOM (2012), utilises Nicholls et al (2008) estimates of the relationship between temperatures and mortality and used the Melbourne specific data from Zander et al (2015) to estimate a dose-response function linking productivity to different maximum daily temperatures. The other socio-economic benefit of local climate regulation that was valued was electricity use which is outside the scope of the preliminary assessment but could be an area for further research.	Yes	**Effect of temperature on productivity:** Estimate the effect of GBI on productivity by adopting the dose-response function from this study which link different (air) temperatures to productivity. (Requires estimates of changes in air temperatures due to GBI). The link between temperature and mortality set out in Nicholls et al (2008) could be explored further to refine the relatively simple approach that's proposed to be used (using AECOM (2012) dose-response function). It is suggested that the information in Dept. of Health (2011) is used (rather than Nicholls et al, 2008) as this sets out the population health impacts of heat using the Victorian Heat Health Information Surveillance System developed by Nicholls et al (2008).
Dept. Human Services (2009) January 2009 Heatwave in Victoria: An Assessment of Health Impacts	This report provides an analysis of the health impacts of the January 2009 Victorian heatwave. Specifically, the population health impact of this extreme heat event has been assessed. Data for the week of the heatwave, 26 January to 1 February 2009, was compared to the same period in previous year(s). The results of this analysis show that there was substantial morbidity and mortality related to the heatwave, with associated demands on health services	No	The simple dose-response function developed by AECOM (2012) will be used in this preliminary assessment for ease of analysis as it can be applied to the general population. The link between temperature and mortality set out in Loughnan et al. (2013) and Dept. of Health (2011) which references Dept of Human Services (2009) could be explored further to refine the relatively simple approach. These sources appear to set out the latest information on the population health impacts of heat in Melbourne.

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Dept. of Health (2011) The population health impacts of heat Key learnings from the Victorian Heat Health Information Surveillance System	This report summarises some of the key learning points from the first two years of heat health surveillance undertaken by the Department of Health in Victoria. It draws on surveillance information obtained from a range of different sources and attempts to answer questions about periods of extreme heat and associated health impacts to support heatwave planning around the state.	No	The simple dose-response function developed by AECOM (2012) will be used in this preliminary assessment for ease of analysis as it can be applied to the general population. The link between temperature and mortality set out in Nicholls et al (2008) could be explored further to refine the relatively simple approach. It is suggested that the information in Dept. of Health (2011) and Loughnan et al. (2013) is used (rather than Nicholls et al, 2008) as these appear to set out the latest information on the population health impacts of heat in Melbourne.
Frontier (2019) Health benefits from water-centric liveable communities	This study references existing literature on the urban cooling effect of GBI including some Melbourne specific studies such as Chen et al (2014) (quoted as NGIA, 2014), Nicholls et al (2008), Loughnan et al (2010) and Dept. Human Services (2009). A Reference to Englart (2015) Climate change and heatwaves in Melbourne – a review, cannot be found online but suggests during the heatwaves in Melbourne in January 2014, there was a 700% rise in Ambulance Service call-outs for cardiac arrests when temperatures spiked at almost 44^{o}C during the heatwave.	No	This study is a review of existing literature. Some of the studies identified in this review will be considered for use in future iterations of the Melbourne environmental-economic account (see comments on other sources in this table).
Hathway, E. A. and Sharples, S. (2012) The interaction of rivers and urban form in mitigating the Urban Heat Island effect: A UK case study	This study investigates the effectiveness that small urban rivers may have in reducing the UHI effect in the spring / summer in Sheffield in the UK. It finds the level of cooling varies with ambient air temperatures, with greater cooling at higher ambient air temperatures (although there are seasonal dependencies and relationships linked to water temperature such that cooling effect is reduced in spring versus summer when the river water temperature is higher). Where temperatures are over 20 degrees centigrade, the cooling effect at the river was 1 degree (i.e. directly above the river), with this falling to approximately 0.5 degrees as you move to 20metres from the river (there is some cooling at 30m depending on urban form and vegetation, 40m shows no cooling effect).	Yes	**Effect of GBI on temperature (rivers):** Although this is a UK specific study and its application to Melbourne is highly uncertain, it is the best available information on the cooling effect of blue infrastructure (e.g. rivers, lakes) and provides an indicative estimate for use within this Melbourne study. The cooling effect of blue infrastructure is an area for further research.
Jamei, E. and Rajagopalan, P. (2017) Urban development and pedestrian thermal comfort in Melbourne.	Human thermal comfort, modelling to investigate effects of Plan Melbourne. Adding green roofs in CBD did not show any improvement in human thermal comfort at ground level.	No	This work is based on future green roof expansion under Plan Melbourne, not the current extent of green roofs. Further work is needed on the effect of green roofs on human thermal comfort and associated socio-economic benefits as opposed to reductions in temperatures only.
Loughnan et al. (2010) The effects of summer temperature, age and socioeconomic circumstance on Acute Myocardial Infarction admissions in Melbourne, Australia	This paper presents a spatial and socio-demographic picture of the effects of hot weather on persons admitted to hospital with acute myocardial infarction (AMI) in Melbourne.	No	The simple dose-response function developed by AECOM (2012) will be used in this preliminary assessment for ease of analysis as it can be applied to the general population. The link between temperature and mortality set out in Loughnan et al. (2013) which references Loughnan et al (2010) and Dept. of Health (2011) could be explored further to refine the relatively simple approach. These sources appear to set out the latest information on the population health impacts of heat in Melbourne.
Loughnan et al. (2013) A spatial vulnerability analysis of urban populations during extreme heat events in Australian capital cities	This study develops a 'tool' to map population vulnerability to extreme heat events in large urban areas, links to Nicholls et al. (2008) and Loughnan et al. (2010) but also provides other Melbourne specific references on the link between temperatures and ill health. The purpose of this "tool" is to assist emergency managers and public health authorities in the development of adaptation strategies to cope with extreme heat by identifying areas that show a high-risk of heat related illnesses and increased service demands during extreme heat events.	No	The simple dose-response function developed by AECOM (2012) will be used in this preliminary assessment for ease of analysis as it can be applied to the general population. The link between temperature and mortality set out in Loughnan et al. (2013) and Dept. of Health (2011) could be explored further to refine the relatively simple approach. These sources appear to set out the latest information on the population health impacts of heat in Melbourne.
Meek, et al (2015) Environmental benefits of retrofitting green roofs to a city block.	This study modelled the potential benefits of retrofitting green roofs in Melbourne in terms of lowering UHI temperatures. It showed that large-scale retrofitting of green roofs across Melbourne's CBD could potentially lower the UHI temperature by 0.7–1.5°C depending on the extent of retrofitting	No	The estimates of temperature reductions are based on future scenario's for expanding green roofs, it does not estimate the cooling effect associated with current green roofs in Melbourne.

NCEconomics (2018) Heatwaves in Victoria: a vulnerability assessment	Estimates the cost to Victoria's economy (by sector and region) of heatwaves. Estimates of the relationship between extreme temperature and productivity (by economic sector) are developed based on (i) available literature (ii) data on the historical relationship between labour productivity by economic sector (Gross Value Added or GVA) and temperatures - excess heat factor) (iii) expert opinion.	No	Dose-response functions linking temperatures to productivity losses are based on excess heat factor not land/surface temperatures. This could be used in the future to develop a more nuanced approach to identifying economic sectors affected by heat if the effect of GBI on excess heat factors can be established.
Nicholls et al. (2008) A simple heat alert system for Melbourne, Australia	This study demonstrates using data from 1979 to 2001 that when mean daily temperature in Melbourne exceeds a threshold of 30°C (mean of today's maximum temperature and tonight's minimum temperature), the average daily mortality of people aged 65 years or more is about 15–17% greater than usual. Similar numbers of excess deaths also occur when daily minimum temperatures exceed 24°C (increases of 19–21% over expected death rate). This information was compiled with the purpose of developing a heat alert system for Victoria based solely on widely available weather forecasts.	No	The simple dose-response function developed by AECOM (2012) will be used in this preliminary assessment for ease of analysis as it can be applied to the general population. The link between temperature and mortality set out in Nicholls et al (2008) could be explored further to refine the relatively simple approach. It is suggested that the information in Dept. of Health (2011) and Loughnan et al. (2013) is used (rather than Nicholls et al, 2008) as these appear to set out the latest information on the population health impacts of heat in Melbourne.

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- **Effect of urban ecosystem assets on temperatures:** Table A10.8. describes the approach to developing an aggregate estimate of the local climate regulating effect of urban ecosystem assets across the urban area within the assessment boundary.

Table A10.8. Proposed method to estimate local climate regulation by urban ecosystem assets within Melbourne urban assessment boundary

Step	Method
1. Estimate the extent (ha/km^2) of green and blue infrastructure assets that provide a local climate regulating function within the urban area of the assessment boundary	Use GIS analysis to estimate the extent of relevant GBI assets (see extent account). This will include the area of urban parks, street trees/canopy cover and freshwaters such as rivers, ponds and lakes.
2. Calculate the percentage of total urban extent covered by each category of GBI asset	Use GIS analysis to estimate the total extent of urban area within the assessment boundary and calculate the proportion of that area covered by GBI assets (Step 1).
3. Estimate the cooling effect of each GBI asset for the urban area within Melbourne.	Calculate the proportional impact on urban temperatures of each GBI asset by adjusting the temperature differentials ($T_{urban/without\ green} - T_{with\ green}$ in ^oC) for each GBI asset according to the percentage of total area covered by that GBI asset (Step 2). *For example, the cooling effect of a park area that makes up 25% of an urban area is assumed to be 25% of the full cooling effect value for parks (i.e. 25% of -1.1^{o}C is 0.28^{o}C).* Where two GBI assets overlap (e.g. canopy cover over rivers or trees in parks) the study team will avoid double counting by selecting the asset with the greatest cooling effect.
4. Estimate the local climate regulating effect (^{o}C) of all GBI assets within the urban area of the assessment boundary	Aggregate the city-level urban cooling effects per category of urban natural capital assessed (from Step 3) into a single combined cooling effect for all of the green and blue infrastructure in Melbourne.
5. Estimate the change in the number of single days per year at different (lower) peak daily temperatures (^{o}C) in Melbourne due to the presence of GBI (relative to a "without GBI measurement baseline").	Identify historical peak daily temperature records: Evidence from the literature indicates that avoided morbidity and mortality effects start to occur at temperatures above 30^{o}C (AECOM, 2012), and that productivity losses begin to occur above 25^{o}C (CRCWSC, 2019). For the purpose of this initial urban account for Melbourne, the interest is in the number of days where peak daily temperature in Melbourne are above 30^{o}C in 2019 which will be obtained from Bureau of Meteorology's historical climate data ('Daily maximum temperature' records) for the Melbourne (Olympic Park) weather station. Estimate what peak temperatures would have been in 2019 without the existence of green and blue infrastructure by adding the single combined cooling effect (^{o}C) for all of the green and blue infrastructure in Melbourne (Step 4) to the historical peak daily temperatures. This application assumes the number of days at each temperature band is evenly distributed within that temperature band and adding the temperature differential to the current

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	distribution of single days within that temperature band so that these days move into the next (hotter) temperature banding. So, if the estimated temperature change due to GBI was 1°C then all the days at each peak temperature would shift into the next temperature band. This will provide estimates of the change in the number of days at different peak temperatures in Melbourne in 2019 under a 'with GBI' scenario (actual 2019 peak temperatures) compared to a 'without GBI' scenario (2019 peak temperatures adjusted by the combined cooling effects).

- **Effect of temperature on health outcomes (morbidity and mortality):** Analysis of the historical relationship or 'dose-response function' between the incidence of human morbidity and mortality and temperatures (°C) for the geographic area of interest can be used to estimate the effect of changes in temperature due to urban ecosystem assets on health outcomes (morbidity and mortality). AECOM estimated these dose-response functions for Melbourne based on a published report from the Department of Human Services (2009) on the health impacts of the 2009 heatwave in metropolitan Melbourne. These AECOM (2012) dose-response functions are set out in Table A10.9. and link the additional morbidity and mortality experienced for temperatures above 30°C.

Table A10.9. Linkages between health outcomes and increased temperatures in Melbourne (AECOM, 2012)

Health outcome		Incidence	Unit
Mortality	Additional mortality due to heat	0.08	Per 100,000 persons per day per 1 degree above 30°C
Morbidity	Additional ambulance attendance due to heat related morbidity	0.09	Per 100,000 persons per day per 1 degree above 30°C
	Additional emergency department presentations due to heat related morbidity	0.52	Per 100,000 people aged 64-74years, per day per 1 degree above 30°C
		3.82	Per 100,000 people aged 74+ years, per day per 1 degree above 30°C

Table A10.10. sets out the proposed approach to apply the cooling effects from the literature (see Table A11.7) to estimate the avoided health outcomes in the urban area within the assessment boundary. This has been informed by the approach developed under the UK urban natural capital account (eftec, 2015). This will not account for the cooling effects of parks, trees and blue infrastructure beyond their boundaries and is therefore considered a conservative approach.

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Table A10.10. Proposed method to estimate avoided health outcomes due to local climate regulation by urban ecosystem assets within Melbourne urban assessment boundary

Step	Method
1. Estimate the change in the incidence of morbidity and mortality in Melbourne due to changes in number of days at different peak temperatures.	Apply the dose-response functions from the literature (Table A10.9) to the change in number of days at different peak temperatures (Table A10.8) and the beneficiary population from ABS data.

A10.6. Recreation

Table A10.11. provides details on the studies that were considered for use to develop a Melbourne specific assessment of the recreation opportunities provided by urban ecosystem assets and how the approaches and data from these studies are proposed for use to inform the Melbourne urban environmental-economic account.

Table A10.11. Review of methods used to estimate the physical provision of recreation from green and blue space within Melbourne

Source	Description	Used in Melbourne study?	
Deloitte Access Economics (2014), The economic contribution of tourist visitation to Victorian parks	This study is quoted in DELWP and Parks Victoria (2015) to include estimates of the number of international and domestic tourism visits to parks in Melbourne which appear to have been taken from survey data by Tourism Research Australia (TRA). Estimates of jobs supported by park-attributable tourism in Melbourne are also provided, which could be relevant if the scope of accounts were expanded to include jobs.	No	If GVA estimates are to be included in future iterations of the account, consideration should be given to the use of this information. Environmental-economic accounts are interested in **all** visits to green-blue infrastructure within Melbourne, not just those that support the tourism industry (i.e. including visits to parks by locals) which will already be captured in the System of National Accounts (SNA). However, this data could be useful for distinguishing between park visits that provide a GVA contribution to the economy (captured in SNA) from those that do not.
DELWP and Parks Victoria (2015), Valuing Victoria's Parks: Accounting for ecosystems and valuing their benefits	This study cites information from Parks Victoria on recreational visits including from the Parks Visitation Monitor Quarter 1-4 (2013) on: i) Number of metropolitan parks visits within Victoria 2003-2013; ii) Number of physically active visits and visitors to urban parks within Victoria 2012-13; iii) Percentage of metropolitan parks visits by recreational activity in 2003-13 including (not mutually exclusive) primarily physical activity (walks, fitness, cycling, jogging, walking the dog), physical activity (primary or secondary reason), sightseeing/spectating, eating/drinking, socialising, journey/tour, passive activities, events/markets. iv) Number of waterways visits to Parks Victoria assets in Victoria in 2003-2013.	Yes	Parks Victoria were contacted to request information on visits to parks within the urban boundary. The information on the percentage of visits that are "active" versus "passive" and/or the type of physical activity was used for valuing the recreational service provided by the parks within the urban Melbourne region.
King et al (2012) Does parkland influence walking? The relationship between area of parkland and walking trips in Melbourne, Australia	Considered the relationship between proximity to parks and recreational activity in Melbourne. Found that more park area in residential environments reduced the odds of walking more frequently. Other area characteristics such as street connectivity and destinations (e.g. schools, shops, restaurants) may underlie these associations by negatively correlating with park area.	No	As noted by the authors, the result is perverse as we might expect that the amount of park area would encourage walking by offering a destination for people to walk to and in, by improving the aesthetics of the neighbourhood. Further consideration should be given to other driving factors such as connectivity and destinations before use in an environmental-economic account (e.g. to consider a method to estimate visits to parks by local population based on park size, without the need for visitor surveys).
MJA (2016), Victoria's nature-based outdoor economy	This study estimates nature-based outdoor activity participation (number of incidences and number of hours) in Victoria, by Tourism Campaign region and by metro. and non-metro. parks in 2014. This was estimated using (a) The ABS *Participation in Sport and Physical Recreation, 2013-14* apportioning a percentage of each activity type to "nature based" and "non-nature based" activity within Victoria and (b) Other nature-based outdoor activity specific participation surveys where appropriate (e.g. Parks Victoria data for walking, running, cycling and swimming activities in parks) with assumptions regarding the duration of activities. Estimates of jobs supported by nature-based outdoor activity in Victoria are also provided, which could be relevant if the scope of accounts were expanded to include jobs.	Yes	Parks Victoria data on visits by recreational activity in metropolitan parks will be used. The broader approach used to estimate nature based participation at Victoria level (i.e. ABS data is not adopted as the ABS data includes all recreation and so assumptions would be needed to estimate recreation in the natural environment.
VicRoads, Bicycle volumes and speeds	This dataset captures the volume of bike traffic at 42 off road locations within urban Melbourne – on both a spatial basis (by location) and tabular form.	No	This data could be used alongside that of Parks Victoria in the future, being careful not to double count visits.

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Annex 11. Estimating the monetary value of ecosystem services in urban Melbourne

The reviewed studies used a mix of exchange and welfare values to monetise the physical provision of ecosystem services as follows:

- Exchange values (e.g. resource rent from market prices) are used where possible, to align with SEEA (2012) guidance and make environmental-economic accounts consistent with the System of National Accounts (SNA), which is the central framework for measuring and presenting information about the stocks and flows within the economy. The SNA will capture the market value of environmental goods and services that are produced using ecosystem services in combination with other inputs (e.g. timber (the good) is produced from biomass (the ecosystem service) using inputs of other inputs such as machinery and labour). Relevant exchange values include food prices (for foraged food, otherwise the contribution of other capitals to the market value needs to be stripped out to estimate the resource rent) and fees for recreational visits;

- Of the studies reviewed, some attempted to isolate the "resource rent" component from the market price. Resource rent isolates the contribution to market price of the ecosystem asset through ecosystem service provision, stripping out the contribution of other inputs to that market price such as labour and machinery. Where not pursued, this is presumably due to a lack of readily available estimates for the cost of non-natural capital (ecosystem asset) inputs and because it was not a proportionate use of resources given the studies were preliminary assessments;

- Some studies used imputed exchange values for ecosystem services which can be estimated using "revealed preference" economic valuation methods which utilise expenditure on related goods, such as hedonic property pricing and travel costs to indirectly measure the value of ecosystem services. Avoided cost was also used in some studies to indirectly measure the value of ecosystem services, for example for example the avoided cost of air conditioning due to local climate regulation and the avoided productivity loss due to the moderation of extreme temperatures (eftec, 2017);

- Some studies also utilise welfare values (which include full consumer surplus value, based on individual willingness-to-pay) for at least some ecosystem services, which are typically:

  a. Estimated using "stated preference" (or "contingent valuation") studies to elicit people's willingness-to-pay for certain outcomes;

  b. Have been developed for policy appraisal purposes to capture the value of ecosystem services that do not contribute to a market good or service (which is predominantly because these ecosystem services are public goods that are enjoyed for free at the point of use e.g. recreation).

The range of monetary valuation approaches used to value ecosystem service provision in the reviewed assessments are set out in Table A11.1. (non-exhaustive list).

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Table A11.1. Example metrics for ecosystem service valuation

Ecosystem service		Monetary metric (per year)	Monetary approaches
Provisioning	Biomass - Food	$ / Kilograms	Resource rent from market prices
	Biomass - Timber	$ / tonne	Stumpage price of timber harvested
	Biomass - Energy	$ / tonne	Resource rent of woodfuel harvested
	Water provision	$ / Ml	Replacement cost of supplying water
Regulating	Air quality regulation	$ / tonnes or μ^3	Avoided health costs to population exposed Willingness to pay to avoid ill health
	Water quality regulation	$ / km or Ml	Avoided cost of infrastructure / wetlands Avoided cost of treating polluted water
	Flood risk regulation	$ / km	Replacement cost of flood control infrastructure
	Landslide regulation	$ / ha	Avoided costs of land rehabilitation costs
	Coastal protection	$ / km	Avoided cost of infrastructure (e.g. sea wall) Avoided damage costs
	Global climate regulation	$ / tCO_2e	Avoided cost of carbon mitigation Social (damage) cost of climate change Market price of carbon
	Local climate regulation	$ / °C	Avoided health costs Avoided loss in GVA Avoided air-conditioning / energy cost
	Storm water management	$/Avoided runoff	Avoided stormwater control costs
	Noise regulation	$ / dBA	Avoided health costs Quality adjusted life year - willingness to pay
Cultural	Recreation	$ / Number visits	Willingness to pay for recreational activity Tourism expenditure/GVA Quality adjusted life year - willingness to pay
	Tourism	$ expenditure	Hedonic pricing – nature based expenditure
	Education and research	$ / visit	Cost of educational visits
	Existence / Option value	$ / species / habitat	Charitable donations Willingness to pay for existence
	Social cohesion/community	$ / hour	Hourly wage rate of volunteers
	Historic and contemporary cultural heritage	*Not considered appropriate* [a]	
Bundle	Amenity	$ / residence	Price premiums from hedonic pricing
Supporting [b]	*Habitat provision*	*$ / ha*	*Willingness to pay for pristine habitat*
	Genetic diversity	*$*	*Willingness to pay for rare / threatened species*
	Nursery populations	*$*	*Value of increased commercial fishing product*
	Pollination	*$ / kg*	*Resource rent of crops affected by pollination* *Avoided cost of artificial pollination*
	Soil cycle regulation	*$ / ha*	*Avoided productivity loss* *Avoided cost of fertiliser*
	Water cycle regulation	*$ / Mg per L*	*Avoided productivity loss*
	Nitrogen cycling	*$ / km*	*Avoided cost of infrastructure / wetlands*
	Pest and disease control	*$ / ha*	*Avoided productivity loss* *Avoided cost of pesticides*

[a] It is not considered appropriate to place a monetary value on natural assets that are protected for their cultural heritage value to people (e.g. shipwrecks arboreal Avenues of Honour). This is because assets that are protected for their cultural value should not be compared to / traded off against the value of other ecosystem services (e.g. in cost-benefit analysis).

[b] As noted above, valuing supporting services is considered by the study team to be acceptable so long as the *indirect* contribution to socio-economic benefits (through supporting the ecological functioning of ecosystems) is estimated in a way that avoids double counting the value that the natural environment provides to society. However, given the conceptual and practical challenges

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associated with this, it is proposed that the Melbourne EEA assessment focuses on quantifying and valuing "final ecosystem services" only, which are defined as ecosystem services that *directly* contribute to human wellbeing through the benefits that they support.

Whilst estimating the physical (kilograms) and monetary reliance of final services (e.g. food production) on intermediate or supporting services (e.g. natural pollination) is both worthwhile and legitimate from an economic perspective, reporting its value *alongside* the (ecosystem asset resource rent) value of final services (e.g. crop production) in an environmental-economic account risks double counting (and therefore overstating) the value of ecosystem assets. Double counting can also occur when the contribution of multiple supporting services to the same final ecosystem service are assessed and valued separately.

Valuing supporting services is considered by the study team to be acceptable so long as the *indirect* contribution to socio-economic benefits (through supporting the ecological functioning of ecosystems) is estimated in a way that avoids double counting the value that the natural environment provides to society. Given the conceptual and practical challenges associated with this, the Melbourne assessment will focus on quantifying and valuing "final ecosystem services" as far as possible. "Final ecosystem services" are defined as ecosystem services that *directly* contribute to human wellbeing through the benefits that they support, see Table 10. This is consistent with the ONS (2016) study developing UK environmental-economic accounts which recommend the exclusion of supporting services in order to avoid double counting.

The studies reviewed do not include Traditional Owner (TO) living cultural values. This could be due to these studies not being located in areas with TO communities, rather than because the environmental-economic accounting framework does not include concepts of value beyond monetary value.

The SEEA-EEA (2020c) revision guidance on monetary valuation notes that accounts should be developed using exchange values which are defined as "the total value of income, production and expenditure as evidenced by transactions" (Brouwer et al., 2013) "or value at which goods and services could be exchanged for cash" (SEEA-EEA, 2020d) and measured as the product of market prices and quantities (eftec, 2015):

"The primary purpose of environmental-economic accounting is to integrate information on ecosystems with measures of economic activity. To align with SNA principles, the environmental-economic accounts…record entries based on the exchange value concept. While this approach supports alignment with the accounting values of the national accounts, and hence with macro-economic policy, there are other monetary approaches and valuation concepts such as welfare values/willingness to pay and total economic values that have been extensively used in other policy contexts such as for cost-benefit analysis or within environmental policy.

The alignment with SNA principles also implies that the monetary values recorded in the environmental-economic accounts reflect the current use of ecosystems. The monetary values reported reflect current use of the environment and are based on the existing management regimes and institutional arrangements regardless of whether the associated patterns of use may be considered (un)sustainable or (in)efficient."

The fact that environmental-economic accounts might include values for uses (e.g. of ecosystems) that are inefficient or unsustainable presents a problem for the use of accounts to inform government decision making. This is because it is the role of government to address issues of inefficiency and unsustainability in order to maximise societal welfare. It is for this reason that the economic values that are used to inform government decision making (e.g. in cost-benefit analysis) measure the *total* economic value of a good or service in terms of "its contribution to human welfare" (Brouwer et al. 2013; eftec, 2015). In order to satisfy the requirements of the SEEA-EEA and also be useful for informing government decision-making, the Melbourne EEA will develop estimates of exchange values (in order to develop SEEA-EEA compliant environmental-economic account) alongside welfare values (for informing policy decisions).

The SEEA-EEA revision process outlines the techniques that have been developed over the last decade for imputing

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exchange values for non-market goods and services for their application in accounting (Barton et al, 2019; UN, 2019; SEEA-EEA, 2020c). See Table 11.2. which summarises these techniques and describes the way in which they can be used to impute unit prices consistent with the exchange value concept.

Irrespective of the method used, economic input costs (including labour, produced capital and intermediate inputs) need to be deducted to arrive at the value of an ecosystem service (SEEA-EEA, 2020e). The remaining sections of this Annex provide details on the studies that could be used to estimate the monetary value of the seven ecosystem services selected for inclusion within the urban Melbourne EEA.

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Table 11.2. Techniques for economic valuation in environmental-economic accounting (Barton et al, 2019; UN, 2019; SEEA-EEA, 2020c)

Valuation approaches			Use in Melbourne account
Market price for ecosystem service available	Directly observable		The most convenient method to apply for valuation is one based on a direct observation of the market price of the ecosystem service when that is available. Stumpage values charged to timber logging businesses are an example of directly observed prices. Should only be applied directly for gathering of wild products, not for commercial cultivation on the basis that the value of crops includes labour and capital (i.e. a resource rent calculation is required).
	Price from similar market		When market prices are not observable, valuation according to market price equivalents may provide an approximation to market prices. For example, observed prices from emission trading systems which may be used to value carbon sequestration services by forest ecosystems even if these ecosystems are not explicitly covered by the emission trading system.
No market price available	Production function based	Resource rent	The resource rent method places a value on an ecosystem service by taking the gross value of the final products to which the ecosystem service provides an input and then deducts the cost of all other inputs, including labour, produced capital and intermediate inputs. For example, for food a fraction of the market price is needed and can be estimated by applying a single fixed percentage based on a research study across all estimates of income less costs methods. As stated above, irrespective of the methods used, economic inputs need to be deducted to arrive at the contribution of the ecosystem service.
		Productivity change / Production function	In the productivity change method, the ecosystem service is considered an input into the production function of a marketed good. Thus, changes in the service will lead to changes in the output of the marketed good other things being equal. The value of the change in the ecosystem service is therefore estimated as the change in the market value of production consequent upon a change in the supply of the ecosystem service. For example, the contribution of ecosystems to the tourism industry could be valued at the fraction of tourism revenue spatially based on geotagged social media data. That is, the fraction of tourists visiting a specific ecosystem type is determined by their social media activity. That fraction is then applied to total tourism revenues.
	Cost based	Replacement cost / Shadow project	The replacement cost method estimates the cost of replacing the ecosystem service by something that provides the same benefits. The validity of the replacement cost approach to estimate exchange values depends upon three conditions being maintained: i) the substitute can provide exactly the same function as the ecosystem service being substituted for; ii) the substitute used is actually the least-cost alternative; and iii) evidence indicates an actual willingness to pay for the alternative to the ecosystem service if it were to be no longer supplied.
		Avoided damage costs (least cost alternatives if less than willingness to pay)	The avoided damage costs method estimates the value of ecosystem services based on the costs of the damages that would occur due to the loss of these services. These "avoided costs" are appropriate so long as the least cost alternative is less than the willingness to pay. This includes avoided storm damage provided by mangroves being estimated through the damages to property avoided by the presence of the mangrove. This requires knowledge of the risk to property with and without the mangroves in place. Willingness to Pay (WTP) is the amount affected people are willing to pay to avoid the damage and needs to be determined separately by survey or interview.
		Defensive expenditure	The defensive expenditure method is based on the amount of money that individuals and communities spend on preventing or mitigating negative effects and damages caused by adverse environmental impacts. For example, extra filtration for purifying polluted water, air conditioning for avoiding polluted air. The expenditures incurred are considered a lower bound estimate of the benefits of mitigation, since it is assumed that the benefits derived from avoiding damages are at least equal to the costs incurred to avoid them These expenditures are already part of the SEEA Central Framework. They describe the amount societies currently spend on environmental protection / conservation activities.
		Consumer expenditures	The consumer expenditure approach estimates the exchange value of recreation related ecosystem services by aggregating the expenditures incurred by households or individuals to reach and access a recreational area. In this approach it is assumed that the actual spending of households represents an approximation of the value provided by these ecosystem services but a challenge in applying this method is determining the share of the expenditures that relates to the ecosystem contribution.
	Opportunity cost	Opportunity cost of alternative use (e.g. of land)	This approach imputes prices of ecosystem services by measuring the forgone benefits of not using the same ecosystem asset for alternative uses. For example, the value of ecosystem services arising from not harvesting trees for timber can be measured by using the forgone income from selling timber. Thus, this approach measures what has to be given up for the sake of securing the ecosystem services.

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	Simulated exchange value (opportunity cost of current use)		The simulated exchange value estimates the opportunity cost of not trading on the market the ecosystem services associated with the current use of the ecosystem asset, given the current ecosystem management objectives. For example, if the manager of a National Park decides not to charge visitors, the opportunity cost estimated with the SEV are the foregone benefits arising from not charging the visitors any entrance fee. For example, the contribution of ecosystems to "recreation" (i.e. nearby use) is recommended to be valued at "simulated exchange value". That is, as though these non-market services were internalised (i.e. if it were actually marketed). This requires estimating demand based on non-market valuation techniques such as asking beneficiaries their willingness to pay for the service. This is then combined with knowledge of the supply and market structure. This can be estimated using a simplified approach involving simply multiplying 50 per cent of the visitors by the median willingness to pay (Barton et al, 2019), which is purported by Caparrós et al. (2017) to provide a reasonable approximation of the simulated exchange value estimated using a more sophisticated approach.
Based on consumer preferences	Stated preference	Contingent valuation	The contingent valuation (CV) method is a survey-based stated preference technique that elicits people's behaviour in constructed markets. In a contingent valuation questionnaire, a hypothetical market is described where the good in question can be traded. This contingent market defines the good itself, the institutional context in which it would be provided, and the way it would be financed. Respondents are asked about their willingness to pay for, or willingness to accept, a hypothetical change in the level of provision of the good, usually by asking them if they would accept a particular scenario. Respondents are assumed to behave as though they were in a real market (OECD, 2018). A typical application of these methods yields values that include consumer surplus. Consequently, to use the results of these methods to derive exchange values, it is necessary to apply them using the simulated exchange value method.
		Choice experiment	Choice experiments are those where an individual is offered a set of alternative levels of supply of goods or services (typically two or three), in which the characteristics vary according to defined dimensions of quality and cost. By analysing preferences across these different bundles of characteristics, it is possible to obtain the value placed by the individuals on each of the characteristics, provided (i) the bundles include a cost variable; and (ii) a baseline bundle is included that represents the status quo. A typical application of these methods yields values that include consumer surplus. Consequently, to use the results of these methods to derive exchange values, it is necessary to apply them using the simulated exchange value method.
	Revealed preference	Hedonic pricing	The hedonic pricing method estimates the differential premium on property values/rentals (or for other composite goods) derived from proximity to some environmental characteristic. In order to obtain a measure of how the environmental characteristic affects the value of houses or other properties, all other variables of the house (number of rooms, central heating, garage space, etc.) are standardised. Moreover, any unit of housing is completely described by geographical, neighbourhood and environmental attributes. For example, amenity value - the contribution of ecosystems to "adjacent use" (such as reflected in property value) is suggested to be valued using hedonic pricing using a large sample of property sales data to determine the additional prices of properties being adjacent to desirable ecosystems (e.g., coast, beach, coral reefs, pristine protected area, etc.).
		Travel costs	The travel cost method (TCM) estimates the demand function for recreation by observing the number of trips that take place at different costs of travelling. Costs of travelling include data on the expenditures incurred by households or individuals to reach a recreational site, entrance fees and the opportunity cost of time to travel and visit the site. Subtracting the actual costs incurred (i.e. excluding opportunity costs of time) from the estimated demand function gives the consumer surplus for a given number of visits. To impute an exchange value for use in environmental-economic accounting, the TCM results must therefore be applied using the simulated exchange value method.

A11.1. Air filtration

Table A11.3 provides details on the studies that could be used to develop a Melbourne specific assessment of the monetary value of the air quality regulating service provided by urban ecosystem assets and how the approaches and data from these studies are proposed for use to inform the Melbourne urban environmental-economic account.

Based on the reviewed literature from around the world, numerous studies have adopted an “impact pathway” approach to estimating the monetary value of health outcomes associated with changes in population exposure to air pollution. This review did not identify a full impact pathway approach for Australia (i.e. including economic valuation) and so there are no location-specific damage costs for Australia/Victoria. The Australian studies reviewed instead use average damage costs (i.e. for a defined geographic area) derived in other locations and adjust these for the Australian context to estimate the health impacts and associated economic value of pollution removal by vegetation.

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Table A11.3. Review of methods used to estimate the monetary value of air filtration from green and blue space within Melbourne

Source	Description	Used in Melbourne study?	
eftec (2017) A study to scope and develop urban natural capital accounts for the UK	In this study, the health benefits of air quality regulation were calculated from the change in pollutant exposure from the EMEP4UK scenario comparisons (discussed in Table 14). UK specific damage costs per unit exposure to different pollutants were applied to the benefitting population at local authority level for a range of avoided health outcomes: - Respiratory hospital admissions; - Cardiovascular hospital admissions; - Loss of life years (long-term exposure effects from PM2.5 and NO2); - Deaths (short-term exposure effects from O3) The value of health benefits of air quality improvement were estimated using reductions in the following key forms of health care costs: - Mortality costs: from the lowered life expectancy or deaths brought forward. These range from £18,000 to £35,000 (Defra, 2014). The primary source used in the IGCB guidance for the valuation of this evidence is the paper by Chilton et al. (2004), which estimates the value of a life year (VOLY) in good health (i.e. a willingness-to-pay value); - Morbidity costs: from the increased incidence of certain illnesses, such as those affecting the cardiovascular and respiratory systems. These range from £2,600 to £10,700 (Defra, 2014). These costs can be broken down into three components (IGCB, 2007): - Resource costs: the medical costs to the National Health Services and private costs of dealing with the illness, these are exchange values; - Opportunity costs: the lost productivity and opportunity cost of leisure (including unpaid work) which are valued based on salary costs of absent individual (i.e. exchange value); and - Disutility: disutility of ill health to the individual and their family and friends which is a willingness-to-pay value. Defra guidance on health damage costs referred to in this study has since been replaced, but updated guidance (Defra 2020) does provide damage costs (£/tonne) for a number of pollutants at an averaged national level for the UK.	No	Damage costs used in this study are calculated using UK location specific inputs (such as population density and health risk assessments) and are not directly applicable within the Australian/Victorian context (i.e. suitable adjustments would be needed).
AECOM (2015) Developing ecosystem accounts for protected areas in England and Scotland: Technical Appendix	This study estimates the value of air quality regulation of vegetation in a protected area in terms of PM10 absorption by applying average damage cost per tonne of pollutant removed in a rural area from the Defra-led Interdepartmental Group on Costs and Benefits (IGCB) (Defra, 2013), across all people living in the protected area. (The average damage costs per tonne of pollutant removed assume an average impact on an average population affected by changes in air quality). The study assumes that the benefit of sequestering a tonne of PM10 is equivalent to the avoided damage of releasing a tonne of PM10 in a rural area using the IGCB central estimate of £15,041 (Defra, 2013).	No	Damage costs used in this study are calculated using UK location specific inputs (such as population density and health risk assessments) and are not directly applicable within the Australian/Victorian context (i.e. suitable adjustments would be needed).
Aurecon (2018) Environmental & health impact assessment – Final report for Infrastructure Victoria	This study uses an impact pathway approach to estimate changes in health outcomes from exposure to $PM_{2.5}$ and NO_x. Dose-response functions are applied to estimate a percentage change in health incidence due to a unit change in pollutant concentration levels (e.g. exposure to a 1 ug/m^3 increase in $PM_{2.5}$ for 24 hours increases the risk of hospital admission for respiratory disease between 0.003-0.004 per cent). These relative risk assumptions are mostly based on the Australian National Environment Protection Council's discussion paper on Air Quality Standards (2010) which reviews international research on the health effects of air pollutants including Australian studies where they exist. Changes in health incidence are reported using Disability Adjusted Life Years (DALY), which measure the aggregate burden of mortality and morbidity experienced by a population. This study doesn't monetise the DALYs, but this could be done by applying a Value of Statistical Life Years to the DALYs lost (see Cropper & Khanna, 2014).	No	To use the dose-response functions in this study, estimates of changes in pollutant concentrations would be needed which are not proposed to be quantified in this urban Melbourne EEA
Jones, R. N. and Ooi, D. (2014) Living Brooklyn: Baseline Report on the Economics of the Urban Water Cycle	This study calculated lost welfare for PM10 for people downwind of pollution from the Brooklyn Industrial Precinct (PM10 and PM2.5), west of Melbourne based on the benefit transfer of the US studies on welfare in this report's section on Health and Wellbeing. This was a point-source pollution problem where it was possible to isolate specific damage, with up to 18 daily exceedances of regulated limits of PM10 each year. For PM10, they calculated an annual range of $0.16 to $0.86 per m^2 health and welfare benefits based on deposition rates of 3 to 8 g per m^2 on trees. For PM2.5, direct health benefits were $0.35 to $2.89 for deposition rates of 0.13 to 0.36 g per m^2 per yr.	No	This study was not selected on the basis that it focused only on one geographic region within Melbourne, as opposed to providing a Melbourne wide estimate. Future work on the urban Melbourne EEA could use the estimating from this study to provide a range of values / sensitivity.

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in the Brooklyn Industrial Precinct in Melbourne.			
PAE Holmes (2013) Methodology for valuing the health impacts of changes in particle emissions – Final Report for NSW EPA	This study reports a damage cost of $190,000 (A$2011) per tonne of PM2.5 for Melbourne. This value has been estimated by applying the commonly adopted economic technique of value transfer to damage cost values from the UK Department of Environment, Food and Rural Affairs (Defra, 2013). The Defra damage costs are based on the UK Value of a Life Year (VOLY) and use the UK rate of all-cause mortality and the UK rates of respiratory and cardio-vascular hospital admissions. Value transfer involves adjusting monetary values for differences between the study context (in this case the UK) and the policy context (in this case Melbourne). This study adjusted the UK damage costs to take into account the difference between: - **Societal preferences and income**: by adjusting for differences in the VOLY between the UK (from Chilton et al, 2004) and Australia (from Australian Safety and Compensation Council, 2008). - **Prices:** by adjusting for differences in currency and, inflation, population density and exposure. - **Population density:** A linear regression function was then fitted to the adjusted damage cost and population density data. Unit damage costs were then developed for specific geographical areas of Australia using a simplified and standardised method, allowing users to relate the location of emissions to an approximate population-weighted exposure. For each ABS Significant Urban Area (SUA) in Australia, population density was used in conjunction with the regression function to determine a unit damage cost.	Yes	The estimated damage cost of PM2.5 for Melbourne is used to provide an indicative value of the air quality regulating service provided by urban vegetation within Melbourne, with the limitations of this approach clearly and transparently explained.
Parry et al. (2014) Getting energy prices right: From principle to practice	This study estimates the taxes on pollution sources (specifically energy production using coal, natural gas, gasoline and diesel) needed to reflect environmental costs in 156 countries. As part of this work, the study estimates damage costs from local air pollution as follows: - **Estimate population exposure**: 'Intake fractions' were used to estimate how much pollution is inhaled by exposed populations in different countries. These intake fractions were extrapolated to country level by weighting for population density; - **Estimate mortality due to exposure**: baseline mortality rates were established by estimating annual mortality rates from four illnesses (the prevalence of which is increased by pollution) for each country, taking into account the age structure of the population, using Global Burden of Disease data. Increased mortality from air pollution was estimated based on a US study, extrapolated for a best statistical fit for different regions; - **Value change in mortality**: Mortality risk was valued based on an OECD (2012) study, which provides a recommended value for mortality risk in OECD countries (based on stated preference studies mostly in Canada, China, France, UK, US), with extrapolation used to account for differences in per capita income across different countries, but not for other factors such as age. This methodology resulted in damage cost estimates for ground level air pollution in Australia of (US$2010): $9,220/ tonne SO_2, $1,873/tonne NO_x, and $238,099/tonne PM2.5. The study notes estimates presented in this study should be treated with a good deal of caution, given data gaps and controversies (e.g. on the link between air quality and mortality risk). It notes that whilst key country-specific factors have been captured where possible, not all potentially significant factors can feasibly be included.	Yes	The estimated damage cost of SO_2, NO_x and PM2.5 in Australia is used to provide an indicative value of the air quality regulating service provided by urban vegetation within Melbourne, with the limitations of this approach clearly and transparently explained.

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A11.2. Amenity

A review of literature found numerous studies estimating the value of amenity provided by current urban ecosystem assets in Melbourne/Victoria using the hedonic price method (i.e. the increased real estate values associated with urban ecosystem assets), see Table A11.4. which shows:

- The Infrastructure Victoria and Aither (2018) and Cooper et al. (2016) studies are the only identified studies to have used primary research for study areas within Melbourne.
- Most of the studies use value transfer to apply estimates from other studies (i.e. Mahmoudi et al. (2013) in Adelaide; Rossetti (2013) for all of Australia; Thomy et al. (2016) from NSW) to Melbourne. The relevance of the methods and findings from these studies to a Melbourne urban environmental-economic account is uncertain because of the location specific nature of the hedonic pricing method (i.e. it needs to be specific to the Melbourne housing market and population), which means that many of the identified studies have been ruled out for further consideration.
- The Cooper et al. (2016) would be challenging to use to value of the current condition of Melbourne waterways in a Melbourne urban environmental-economic account as these are marginal values (willingness to pay for a per cent improvement in one of four scenarios). Consideration of amenity of value of blue space is therefore ruled out for further consideration in this initial account but is a key area for future research. Other potential sources of information on the value of amenity from blue space that were identified after this decision was made are set out in Table A11.4.
- The City of Melbourne method for valuing the “amenity” of street trees is based on a formula that is not based on the provision of ecosystem services from ecosystem assets (trees) and so is inconsistent with environmental-economic accounting.
- The proposed option for valuing the amenity benefits of urban ecosystem assets in Melbourne is to use *The Victorian Amenity Valuation Tool for Cost Benefit Practitioners* produced by Infrastructure Victoria and Aither (2018) to develop a method for estimating the total value of green spaces across Melbourne using the price elasticities associated with adding another (i.e. marginal) green space (of undefined size) across Local Government Areas.
- The study team considered developing a simple and crude approach option using the 5 per cent to 7 per cent price premium adopted by DELWP and Parks Victoria from Rossetti (2013). However, this was dropped as it would not allow for estimates of the variation in price premiums associated with access to green space across Melbourne which would be expected given differences in the availability of substitute sites across the city (amongst other things).

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Table A11.4. Review of methods used to estimate the monetary value of amenity from urban ecosystems within Melbourne

Source	Description	Used in Melbourne study?	
Infrastructure Victoria and Aither (2018) What makes a locality attractive? Estimates of the amenity value of parks for Victoria	Aither and Infrastructure Victoria used the hedonic pricing method to estimate the value ($) of parks through residents' willingness to pay to live closer to particular types of parks using property prices. This study provides estimates of amenity value of four major types of parks within Victoria using hedonic regression. In Melbourne, it is the metropolitan parks and sport and recreational parks that provide positive amenity (both with a distance elasticity of around -0.012 per cent). Conversely, some parks are considered dis-amenities with positive distance elasticities, specifically community and cultural parks (0.006 per cent), reserves (0.013 per cent) and other parks (0.002 per cent). The study finds that moving from the median to the first percentile of distances from a park is associated with increased property prices of up to $86,000. An accompanying tool *"The Victorian Amenity Valuation Tool for Cost Benefit Practitioners"* has been developed to promote the use of this evidence in project appraisals which can be used to estimate the value of parks given location and certain parameters (e.g. availability of substitute sites).	Yes	Yes, primary research into the price premium associated with access to green space in Melbourne. Infrastructure Victoria provided DELWP with *The Victorian Amenity Valuation Tool for Cost Benefit Practitioners* and it was used to estimate the amenity value of green space across Melbourne.
DELWP and Parks Victoria (2015) Valuing Victoria's Parks: Accounting for ecosystems and valuing their benefits	The valuation method for amenity value used in this study is based on a benefit transfer of multiple hedonic home price studies for urban and peri-urban parks only. The study suggests that the international evidence indicates that the effect of parks on surrounding property prices is between 5% to 20%, and Australian specific evidence suggests similar effects of between 7% to 20% (Cochrane, 2014; Pearson, 2002; Rossetti, 2013), the study used a conservative range from 5% to 7%. This is in line with findings from recent published studies available in the Australian context, such as a 2013 thesis indicating an average increase of 8.6% to 15.6% due an increased Enhanced Vegetation Index (used as a proxy for green infrastructure). Spatial analysis was undertaken to identify the number of immediate neighbours to urban and peri-urban parks managed by Parks Victoria and data on surrounding median home price was reviewed for each park. Consequently, the calculation of the number of households obtaining amenity value from Melbourne's parks provides a conservative estimate, as research suggests that increased home prices gradually drop with distance from the park. Only urban and peri-urban parks were assessed, as the evidence for amenity value for other parks is more limited. Based on the assumption of a 5-7% increase in home value for immediate urban and peri-urban park neighbours, the amenity value for residents immediately surrounding Melbourne's urban and peri-urban parks is $326m to $438m or $21m/yr to $28m/yr.	Yes	This simple and crude method would not allow for estimates of the variation in price premiums across Melbourne which would be expected given availability of substitute sites (amongst other things).
City of Melb (n.d.) Tree valuation in the city of Melbourne	The basic monetary value of a tree is taken from the internationally accepted table of values devised by the American Council of Tree and Landscape Appraisers (ACTLA) and the International Society of Arboriculture. This value is then multiplied by different factors based on tree characteristics including species (trees with a long life span and slow growth rate score highest), aesthetics (solitary feature specimen tree scores highest), locality (city centre main street scores highest) and condition (including trunk condition, growth rate, structural condition, if it has pests or disease, if its contributing to full canopy cover and if it has a long life expectancy).	No	Amenity formula is not based on the provision of ecosystem services from trees and so is inconsistent with environmental-economic accounting.
Cooper et al. (2016) The Value of Melbourne's Waterways	Valued user "experience" under four waterways scenarios based on matrix of high/low ecological values and amenity values using choice experiments to estimate marginal (%) changes in waterway condition.	No	Not publicly available and although primary research, would be challenging to apply the marginal metrics that are valued (willingness to pay for a % improvement in one of four scenarios) to estimate the value of the current condition of Melb. waterways.
Moore, G. (2009) Urban Trees: Worth More Than They Cost	This study estimates an aggregate value for City of Melbourne of $14m by applying an Adelaide based estimate to Melbourne's 70,000 public trees. Disaggregated estimates for different ecosystem services (including "aesthetics" which is taken here to be commensurate with visual "amenity") are based on Moore's method and reference to the original Adelaide study, which is acknowledged by the author as highly uncertain.	No	Based on highly uncertain benefits transfer from Adelaide
NCEconomics (2019) The economic benefits of open space in metropolitan Melbourne	The study uses methods derived in several other studies to estimate the annual property price premiums accruing from proximity to urban open spaces with and without waterways located in Moreland City Council. The unit values were sourced from prior work on riparian open spaces located along urban waterways with specific Vegetation and Riparian Conditions (Thomy et al., 2016); non-riparian urban open spaces (Mekala et al., 2015); and proximity to a golf course (Iftekhar et al., 2018). The property price premium impact from proximity to urban open spaces with and without waterways and the Northern golf course was estimated at $71 million per annum (range $57-105 million) across the Local Government Area (LGA).	No	Values developed using value transfer and are specific to the City of Moreland and therefore it is not deemed to be relevant to apply value transfer to estimate a value for all of Melbourne.
Mekala et al. (2015), Valuing the Benefits of Creek Rehabilitation	This study estimates the socio-economic benefits from investment in urban green infrastructure (rehabilitating an area of Stoney Creek) in a case study area of approximately 4 ha, in the Sunshine precinct of City of Brimbank located in the western suburbs of Melbourne. One of the key ecosystem services anticipated to be achieved by implementing the Stony Creek Rehabilitation Project is increased property values, which is quantified using a spatial hedonic pricing model (adapted from Mahmoudi et al., 2013). The study estimates potential private benefits of AU$3.9 million (current property owners in the area are likely to benefit from the amenity value being capitalised into property values) for the project area. Properties immediately adjacent to the project park area will increase in value by 4.5% with the increase in value decaying with the increase in distance.	No	Values developed using value transfer and are specific to the City of Brimbank and therefore it is not deemed to be relevant to apply value transfer to estimate a value for all of Melbourne.

A11.2.1. Detailed methodology and results

Aither and Infrastructure Victoria used the hedonic pricing method to estimate the value ($) of parks through residents' willingness to pay to live closer to particular types of parks using property prices. This relationship is termed the "price elasticity" as it captures the responsiveness of (i.e. the elasticity) of property prices to distance from parks. Their study provides estimates of amenity value of four major types of parks within Victoria using hedonic regression. In Melbourne, it is the metropolitan parks and sport and recreational parks that provide positive amenity (both with a negative distance elasticity of around -0.012 per cent) which means that moving 1 per cent further from the nearest of these park types would be estimated to reduce the house sales price by 0.012 per cent. Conversely (and perhaps perversely) some parks are considered dis-amenities with positive distance elasticities (i.e. house prices increase with increasing distance from these parks), specifically community and cultural parks (0.006 per cent), reserves (0.013 per cent) and other parks (0.002 per cent). The authors speculate that the positive distance elasticity value for community and cultural parks may reflect congestion, the loss of parking for residents around these facilities and the attraction of noisy groups (pers. comm. David Prentice, Infrastructure Victoria). The authors also note that other Melbourne specific studies (Breunig et al, 2018) found positive results (in terms of the effect of greater access to green space on house prices) suggesting that there could be geographical heterogeneity in how small parks are valued. Given this uncertainty around the value of small parks, the focus on this assessment will be on metropolitan parks and sports and recreational parks only.

Aither and Infrastructure Victoria developed the Amenity Tool to promote the use of the evidence on house price premiums associated with parks in project appraisals. The Tool yields an estimate of the effect on house prices aggregated across the relevant set of properties around the park. A regression coefficient (from the hedonic pricing analysis) provides an estimate of the average effect, it is the aggregation that is the distinctive contribution of the Tool. The Amenity Tool was made available to DELWP to explore its application to value the benefits of green and blue infrastructure assets in Melbourne. The Tool is an interactive model that can be used to estimate the average effect on residential property prices of creating a new (hypothetical) park in a Local Government Area, given the availability to residents of substitute parks (user defined number) within a certain radius (user defined between 0.5km to 5 km). Users are able to select the "type" of park to value including metropolitan parks (e.g. Albert Park), community and cultural amenities (e.g. Melbourne showgrounds), sport and recreational (e.g. Yarra Bend golf course) and national and state parks (e.g. Wilson's Promontory). However, the new park is non-specific insofar as the aggregation of amenities means that the estimates are averages and do not capture quality differences within the same amenity types (Aither, 2017). For example, one metropolitan park may have paths, benches and toilets while another metropolitan park may have none of these facilities, however both parks would be considered to be of the same type and quality in the Amenity Tool.

Tables 11.5. and 11.6. detail the detailed steps behind the calculation of the estimated value from amenity from existing parks within the assessment boundary for metropolitan parks and sports and recreation parks respectively.

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Table A.11.5. Estimated value of amenity from metropolitan parks within the assessment boundary using the Amenity Tool developed by Infrastructure Victoria and Aither (2018)

LGA	A: No. of metropolitan parks[91]	B: Total metropolitan park area (sq.km)	C: Ave. size of metropolitan park (sq.km)	D: Area of LGA (sq.km)	E: Proportion of LGA covered by metropolitan park (%)	F: Area of 2km radius (sq.km)	G: Est. area of metropolitan park in 2km radius (sq.km)	H: Est. no of metropolitan parks in 2km radius	I: Est. no of substitutes in 2km radius	J: Est. value of additional metropolitan park ($)[92]	K: Est. total value of metropolitan parks in LGA ($)	L: Est. annualised value of total metropolitan parks ($)[93]
			$\frac{B}{A}$		$\frac{C}{D}$	$\pi * 2^2$	$F * E$	$\frac{G}{C}$	$H - 1$		$J * A$	$\frac{K * r}{1-(1+r)^{-t}}$
Banyule	2	2.893	1.447	62.628	4.62%	12.566	0.581	0.401	0	$148,565,262	$297,130,524	$20,823,134
Boroondara	2	0.008	0.004	60.194	0.01%	12.566	0.002	0.418	0	$483,218,727	$966,437,455	$67,728,676
Brimbank	1	3.520	3.520	123.382	2.85%	12.566	0.359	0.102	0	$62,361,645	$62,361,645	$4,370,352
Darebin	1	0.002	0.002	53.470	0.00%	12.566	0.000	0.235	0	$206,387,995	$206,387,995	$14,463,828
Hobsons Bay	1	0.017	0.017	64.539	0.03%	12.566	0.003	0.195	0	$98,574,236	$98,574,236	$6,908,158
Kingston	1	0.000	0.000	91.629	0.00%	12.566	0.000	0.137	0	$120,753,482	$120,753,482	$8,462,496
Knox	1	5.830	5.830	113.883	5.12%	12.566	0.643	0.110	0	$77,040,410	$77,040,410	$5,399,051
Manningham	2	2.781	1.390	113.335	2.45%	12.566	0.308	0.222	0	$97,151,893	$194,303,787	$13,616,958
Maribyrnong	2	0.512	0.256	31.245	1.64%	12.566	0.206	0.804	0	$181,131,970	$362,263,940	$25,387,734
Maroondah	1	0.012	0.012	61.403	0.02%	12.566	0.003	0.205	0	$112,144,942	$112,144,942	$7,859,203
Melbourne	2	0.415	0.208	37.701	1.10%	12.566	0.138	0.667	0	$429,674,118	$859,348,237	$60,223,781
Monash	1	2.181	2.181	81.482	2.68%	12.566	0.336	0.154	0	$204,182,878	$204,182,878	$14,309,292
Moonee Valley	2	1.063	0.531	43.096	2.47%	12.566	0.310	0.583	0	$235,358,332	$470,716,664	$32,988,184
Nillumbik	2	0.169	0.084	432.152	0.04%	12.566	0.005	0.058	0	$8,345,213	$16,690,427	$1,169,678
Port Phillip	2	2.225	1.113	21.039	10.58%	12.566	1.329	1.195	0	$837,111,850	$1,674,223,700	$117,330,877
Whitehorse	3	0.652	0.217	64.273	1.01%	12.566	0.127	0.587	0	$237,812,662	$713,437,987	$49,998,280
Yarra	2	0.059	0.030	19.557	0.30%	12.566	0.038	1.285	0	$592,012,173	$1,184,024,346	$82,977,331
Total	**28**										**$7,620,022,654**	**$534,017,014**

[91] Based on the 'Metropolitan Parks' class of the Public Land Management (PLM25) dataset, with the parcels of the same park manually combined

[92] Output of Amenity Tool, updated to 2021 dollars from using CPI adjustment from June 2016 to June 2021 for New dwelling purchase by owner-occupiers, Melbourne.

[93] The annualised value is calculated using the Equivalent Annual Cost calculation, which converts the capitalised value of amenity (asset prices) into an annual (flow) value; r (discount rate) = 7 per cent, t (time periods) = 100 years

Table A.11.6. Estimated value of amenity from sports and recreation parks within the assessment boundary using the Amenity Tool developed by Infrastructure Victoria and Aither (2018)

LGA	A: No. of sports and recreation parks[94]	B: Total sports and recreation park area (sq.km)	C: Ave. size of sports and recreation park (sq.km)	D: Area of LGA (sq.km)	E: Proportion of LGA covered by sports and recreation park (%)	F: Area of 2km radius (sq.km)	G: Est. area of sports and recreation park in 2km radius (sq.km)	H: Est. no of sports and recreation parks in 2km radius	I: Est. no of substitutes in 2km radius	J: Est. value of additional sports and recreation park ($)[95]	K: Est. total value of sports and recreation parks in LGA ($)	L: Est. annualised value of total sports and recreation parks ($)[96]
			$\frac{B}{A}$		$\frac{C}{D}$	$\pi * 2^2$	$F * E$	$\frac{G}{C}$	$H - 1$		$J * A$	$\frac{K * r}{1-(1+r)^{-t}}$
Banyule	42	4.185	0.100	62.628	6.68%	12.566	0.840	8.427	7	$7,125,510	$299,271,441	$20,973,171
Bayside	42	4.184	0.100	37.448	11.17%	12.566	1.404	14.094	13	$10,244,733	$430,278,796	$30,154,267
Boroondara	54	3.175	0.059	60.194	5.27%	12.566	0.663	11.273	10	$18,237,506	$984,825,345	$69,017,313
Brimbank	38	2.583	0.068	123.382	2.09%	12.566	0.263	3.870	3	$7,636,714	$290,195,144	$20,337,098
Cardinia	31	3.051	0.098	1,281.754	0.24%	12.566	0.030	0.304	0	$2,869,159	$88,943,914	$6,233,258
Casey	68	8.494	0.125	397.101	2.14%	12.566	0.269	2.152	1	$8,698,551	$591,501,474	$41,452,876
Darebin	48	3.131	0.065	53.470	5.86%	12.566	0.736	11.281	10	$7,410,442	$355,701,196	$24,927,812
Frankston	49	6.789	0.139	129.857	5.23%	12.566	0.657	4.742	4	$4,028,510	$197,396,973	$13,833,731
Glen Eira	30	2.288	0.076	38.690	5.91%	12.566	0.743	9.744	9	$14,670,690	$440,120,711	$30,843,996
Greater Dandenong	40	4.034	0.101	129.498	3.11%	12.566	0.391	3.882	3	$6,856,647	$274,265,874	$19,220,762
Hobsons Bay	45	2.828	0.063	64.539	4.38%	12.566	0.551	8.762	8	$4,630,026	$208,351,183	$14,601,410
Hume	75	3.258	0.043	503.227	0.65%	12.566	0.081	1.873	0	$14,521,762	$1,089,132,172	$76,327,215
Kingston	57	5.961	0.105	91.629	6.51%	12.566	0.817	7.817	7	$6,135,319	$349,713,157	$24,508,165
Knox	56	4.925	0.088	113.883	4.32%	12.566	0.543	6.179	5	$5,315,973	$297,694,477	$20,862,657
Manningham	34	2.514	0.074	113.335	2.22%	12.566	0.279	3.770	3	$13,190,584	$448,479,842	$31,429,810
Maribyrnong	26	1.428	0.055	31.245	4.57%	12.566	0.574	10.457	9	$7,252,042	$188,553,096	$13,213,945
Maroondah	39	3.571	0.092	61.403	5.82%	12.566	0.731	7.981	7	$5,576,694	$217,491,083	$15,241,941
Melbourne	30	3.057	0.102	37.701	8.11%	12.566	1.019	10.000	9	$16,801,916	$504,057,467	$35,324,733
Melton	32	6.458	0.202	527.759	1.22%	12.566	0.154	0.762	0	$9,523,633	$304,756,266	$21,357,552
Mitchell	3	0.783	0.261	2,861.455	0.03%	12.566	0.003	0.013	0	$461,133	$1,383,400	$96,950
Monash	59	4.684	0.079	81.482	5.75%	12.566	0.722	9.099	8	$9,687,500	$571,562,492	$40,055,536
Moonee Valley	38	2.347	0.062	43.096	5.45%	12.566	0.684	11.080	10	$8,973,926	$341,009,178	$23,898,184
Moreland	55	2.104	0.038	51.039	4.12%	12.566	0.518	13.542	13	$6,687,327	$367,802,994	$25,775,915
Mornington Peninsula	85	9.809	0.115	728.379	1.35%	12.566	0.169	1.466	0	$20,824,483	$1,770,081,055	$124,048,634
Nillumbik	33	0.598	0.018	432.152	0.14%	12.566	0.017	0.960	0	$9,079,125	$299,611,136	$20,996,977
Port Phillip	14	2.230	0.159	21.039	10.60%	12.566	1.332	8.362	7	$48,175,769	$674,460,771	$47,266,727
Stonnington	28	1.070	0.038	25.633	4.17%	12.566	0.525	13.727	13	$28,403,894	$795,309,037	$55,735,865
Whitehorse	42	2.729	0.065	64.273	4.25%	12.566	0.534	8.212	7	$10,892,705	$457,493,607	$32,061,502
Whittlesea	49	2.206	0.045	489.684	0.45%	12.566	0.057	1.257	0	$17,750,288	$869,764,109	$60,953,734

[94] Based on the 'Sports-fields and organised recreation' class of the VPA Open Space dataset, with the parcels of the same park manually combined

[95] Output of Amenity Tool, updated to 2021 dollars from using CPI adjustment from June 2016 to June 2021 for New dwelling purchase by owner-occupiers, Melbourne.

[96] The annualised value is calculated using the Equivalent Annual Cost calculation, which converts the capitalised value of amenity (asset prices) into an annual (flow) value; r (discount rate) = 7 per cent, t (time periods) = 100 years

Unofficial

Wyndham	27	3.787	0.140	541.903	0.70%	12.566	0.088	0.626	0	$15,730,642	$424,727,332	$29,765,216
Yarra	22	2.059	0.094	19.557	10.53%	12.566	1.323	14.136	13	$17,378,778	$382,333,113	$26,794,197
Yarra Ranges	42	3.726	0.089	2,468.949	0.15%	12.566	0.019	0.214	0	$3,052,022	$128,184,909	$8,983,296
Total	**1,333**										**$14,644,452,744**	**$1,026,294,445**

Unofficial

A11.3. Education

Table A11.7. provides details on the studies that could be used to develop an urban Melbourne specific assessment of the value of educational visits to the natural environment.

Table A11.7. Review of methods used to estimate the monetary value of education from urban ecosystem assets

Source	Description	Used in Melbourne study?	
Marsden Jacob (2016), Victoria's nature-based outdoor economy	This study estimates of the contribution of Victoria's nature-based outdoors sector to the Victorian economy. The contribution to Gross State Product is estimated, with an adjustment for leakage of expenditure on goods and services outside of the Victorian economy. Day and multi-night school excursion expenditure was estimated using the average cost for day trip and overnight activities from the Australian Camping Association's Prices and Occupancy Survey Report 2012 (inflated to 2014/15). Because the respondents are overwhelmingly Victorian, the average figures were expected to be representative.	Yes	The focus of the urban Melbourne EEA is on the societal value of education rather than the contribution to economic output. Therefore, whilst the method to estimate GSP will not be considered, the excursion expenditure on school trips from the latest Australian Camping Association's Prices and Occupancy Survey Report will be used as a representative figure for the "value" (lower bound) of educational visits.
Mourato et al. (2011) UK National Economic Assessment: Assessment of Ecosystem Related UK Cultural Services	This study values educational (day) trips made by schools in 2009 to the London Wetland Centre of £19 per child and the Hanningfield Reservoir of £30 per child. The value of educational trips is estimated as the sum of: - Transport costs: The average cost to parents of a primary and secondary school day trip in the UK was used to value transport costs = between £7.75 and £16.18 per child per trip. - Value of teachers in-vehicle travel time was valued using 125 per cent of their wage (estimated at £35,000 per annum, to reflect the cost of their time and labour overheads). - Value of student time: based on the cost to government of keeping students in education (about £5,140 per student per year).	No	These are UK specific estimated of educational activities and so are not deemed to be the most appropriate to use for this urban Melbourne EEA. However, the method adopted will be used to inform areas for future research to refine the valuation of educational visits to the natural environment within the urban Melbourne EEA boundary.

Unofficial

A11.4. Biomass - Food

Table A11.8. provides details on the studies that could be used to develop an urban Melbourne specific assessment of the value of biomass - food production.

Table 11.8. Review of methods used to estimate the monetary value of food production from green and blue space within Melbourne

Source	Description	Used in Melbourne study?	
Deloitte Access Economics (2016) The economic contribution of Melbourne's foodbowl	This study estimates the value of commercial agricultural production using *ABS Value of Agricultural Commodities Produced* data to determine the gross value ($) of agricultural production across different Local Government Area's (LGA's) within Melbourne.	Yes	**Commercial production:** the approach taken by Deloitte (2016) to estimate the gross value ($) of agricultural production across different Local Government Area's (LGA's) within Melbourne using ABS data can be replicated for the environmental-economic account.
Zainuddin & Mercer (2014) Domestic residential garden food production in Melbourne, Australia: a fine-grained analysis and pilot study	This pilot study collected information on the types of produce that were grown (as well as the total yield) in domestic gardens in 2012-13 and report these in percentages.	Yes	**Household production:** Can be used to identify specific crops that are grown, the equivalent market price of which can be identified (for organic produce) to estimate the value of production.
Melbourne City Rooftop Honey (2020) The Project	The average value of organic honey production ($/kilogram) is available on the Melbourne City Rooftop Honey website.	No	**Honey production:** honey will not be quantified and valued for this initial Melbourne EEA. In the future, the average value of organic honey production minus input costs ($/kilogram) could be applied to the estimate of total honey production within Melbourne.

A11.5. Global climate regulation

The approaches taken to estimating the monetary value of global climate regulation in the urban Melbourne EEA region are summarised below:

i. **Social cost of carbon**:

a. US Government figures on the social cost of carbon: The US Government has released various reports on the social cost of carbon, estimating the value of damage costs associated with greenhouse gas emissions by modelling the total cost today of a tonne of carbon emitted now, summing the full global cost of the damage associated with carbon over the whole of its time in the atmosphere. The latest US government estimate for the social cost of carbon of $59 are adopted (understood to be US Government, 2016) and uprated for inflation to put in present day prices.

b. Hope (2006) value on the social cost of carbon: This approach uses the mean (average) value of the social cost of carbon of $43 (2006 terms) that was estimated by Hope (2006) using the same probabilistic integrated assessment model as used by the Stern Review and uprated for inflation to put in present day prices.

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ii. **Market price / replacement cost:**

- World Bank Carbon Pricing Dashboard: In the absence of a clear carbon price in Australia, the median of existing international carbon market values can be obtained from the World Bank Carbon Pricing Dashboard data (World Bank, 2019) which were approximately $20 per tonne of CO_2e in 2019 and uprated for inflation to put in present day prices.
- Auctions of the Commonwealth's ERF: The average price across previous auctions of the Commonwealth's Emissions Reduction Fund (ERF) of approximately $12/ tonne of CO_2e can be adopted to provide an Australian specific market value.
- IPCC's Fifth Assessment Report: Values consistent with scenarios in the Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment Report (IPCC, 2014) can be applied, with the values converted into Australian dollars for the relevant year using an average annual exchange rate and then escalated to the relevant year using an Australian GDP deflator.[97] Based on a scenario that would provide a likely chance of limiting global temperature increases to below 2°C above pre-industrial levels, the value per tonne of CO2e is $71 (in AUD2019).[98,99] This was uprated for inflation to put in present day prices. It should be noted that the IPCC values do not represent actual prices observed from carbon markets, rather they are derived from hypothetical (modelled) abatement scenarios.

Table A11.9. provides details on the studies that were reviewed for use to develop an urban Melbourne specific assessment of the value of global climate regulating service provided by urban ecosystem assets and how the approaches and data from these studies were used in the urban Melbourne EEA.

[97] Conversion indices used are from the World Bank's World Development Indicators published in the Bank's online databank. World Bank Databank, World Development Indicators, Official exchange rate (LCU per US$, period average): Series code PA.NUS.FCRF, GDP deflator (base year varies by country): Series code NY.GDP.DEFL.ZS, http://databank.worldbank.org/data/
[98] This IPCC scenario assumes global action is taken to keep global temperature rises to below 2°C and is maintained out to 2050. Values are derived from the mean of carbon prices that have been assessed by the IPCC as providing a greater than 66 per cent chance of keeping global temperature increases to below two degrees by 2100 – consistent with atmospheric concentrations of carbon dioxide equivalent to 430-480 ppm.
[99] Values consistent with this IPCC scenario have previously been applied in Victorian Government analysis and decision-making. For example, see Department of Environment, Land, Water and Planning 2020, 'Appendix 12', *Regulatory Impact Statement: Victorian Energy Efficiency Target Amendment (Prescribed Customers and Targets) Regulations 2020*, State of Victoria, Melbourne, pp. 20-22.

Unofficial

Table A11.9. Review of methods used to estimate the monetary value of global climate regulation from ecosystems in the urban Melbourne region

Source	Description	Used in Melbourne study?	
BDA Group (2015) Valuing the benefits of Victorian waterway management	The study suggests a value of $25/t CO_2e could be assumed reflective of the average cost of abatement under the (now discontinued) NSW Greenhouse Gas Abatement Scheme and the rate set under the Commonwealth's now discontinued carbon tax (the rate was set at $23 per tonne of CO_2e in 2012-13, rising to $25.40 in 2014-15).	No	Both values are based on the value of carbon under now discontinued mechanisms.
DELWP and Parks Victoria (2015), Valuing Victoria's Parks: Accounting for ecosystems and valuing their benefits	**Market price of reductions in emissions of carbon dioxide equivalent [100] in current markets**: With the repeal of the Commonwealth Government's carbon price legislation, there is currently no legislated market price of carbon in Australia. Forecasts of international carbon prices for 2020 range from AUD $6 to $80 per tonne of carbon dioxide equivalent. In terms of carbon sequestration from forestry or revegetation projects, current (2015) market transactions through the Carbon Farming Initiative indicate values closer to $23 per tonne carbon dioxide equivalent, however industry stakeholders have indicated that under the newly created Emissions Reductions Fund (ERF) these values are likely to be set at around $5-8 per tonne of carbon dioxide equivalent. For the purpose of this valuation, the originally announced **$15 per tonne of carbon dioxide equivalent sequestered** was used as a lower bound for carbon sequestered in parks. This is consistent with recent voluntary carbon offset programs such as Greenfleet (a carbon offsetting provider).	Yes	**Market price / replacement cost:** Although the specific values set out in the report were not used, the value of carbon across all six auctions of the Commonwealth's Emissions Reduction Fund (ERF) is presented as a lower bound.
	Social cost of carbon: this is the value of damage costs associated with greenhouse gas emissions and the study uses this as an upper bound value. The social cost of carbon is a modelling estimate from a US Government study (US EPA, 2013) of the total cost today of a tonne of carbon emitted now, summing the full global cost of the damage associated with carbon over the whole of its time in the atmosphere, estimated to be US$39 in 2011 dollars which was approximately **AUD$63 per tonne of CO2e** in 2014.	Yes	**Social cost of carbon:** Used the latest version of the report used in this study to represent the social cost of carbon sequestered by ecosystem assets within the assessment boundary. Care was be taken to ensure the physical and monetary values are in commensurate terms (either carbon or CO_2e, see footnote).
DELWP (2016), Marine and Coastal Ecosystem Accounting: Port Phillip Bay	**Market price of reductions in emissions of carbon dioxide equivalent in current markets**: With the repeal of the Commonwealth Government's carbon price legislation, there is currently no legislated market price of carbon in Australia. In the absence of a carbon price in Australia, the Commonwealth's Emissions Reduction Fund (ERF) auctions is presented as providing a broad indication of the average cost of purchasing a set amount of carbon abatement in Australia. The study values carbon using a lower bound of the average cost of abatement in the Australian Emissions Reduction Fund (in the third ERF auction held by the Clean Energy Regulator) in April 2016 of **$10.23 per tonne of CO2-e**. The study also notes that the cost of purchasing emissions reductions in some international markets (such as the United Nation's Clean Development Mechanism) is less than $1 per tonne of CO2-e. The European Union trading scheme is currently around $9 per tonne of CO2-e. Prices in different markets can vary significantly as they are driven by policy ambition rather than the value of abatement.	Yes	**Market price / replacement cost:** Although the specific values set out in the report were not used, the value of carbon across all six auctions of the Commonwealth's Emissions Reduction Fund (ERF) is presented as a lower bound.
	Social cost of carbon: this represents the global benefit of reducing emissions (i.e. avoided damages associated with changes in agricultural productivity, human health, flood risk, ecosystem services and other factors). The study uses this as an upper bound value. The social cost of carbon is a modelling estimate from a US Government study (US EPA, 2013) of the total cost today of a tonne of carbon emitted now, summing the full global cost of the damage associated with carbon over the whole of its time in the atmosphere, estimated to be US$39 in 2011 dollars (around **AUD$57 per tonne of CO2-e** in 2016).	Yes	**Social cost of carbon:** Used the latest version of the report used in this study to represent the social cost of carbon sequestered by GBI within the urban area of the assessment boundary. Care was be taken to ensure the physical and monetary values are in commensurate terms (either carbon or CO_2e, see footnote).
DELWP (2019), Ecosystem Services from Forests in Victoria: Assessment of Regional Forest Agreement Regions	**Market price of reductions in emissions of carbon dioxide equivalent in current markets:** In the absence of a clear carbon price in Australia, the central value used in this study of $20 per tonne of CO_2e has been derived from a median of existing international carbon market values, which were obtained from the World Bank Carbon Pricing Dashboard data (World Bank, 2019). A lower bound value for the study of $12/ tonne of CO_2e was also adopted which aligns with the average price across previous auctions of the Commonwealth's Emissions Reduction Fund (ERF).	Yes	**Market price / replacement cost:** Used the approach identified and used in this study to represent the market value of carbon sequestered by ecosystem assets within the assessment boundary. Care was be taken to ensure the physical and monetary values are in commensurate terms (either carbon or CO_2e, see footnote).
	Social cost of carbon: the study adopts a social cost of carbon of $59 tonne of CO_2e as an upper bound value, which is equivalent to the 2018 social cost of carbon estimate derived by the US Government (US Government, 2016). This represents a different method of valuing the ecosystem service of carbon sequestration, based on a welfare value. This differs from exchange values which are used to value other ecosystem services in this study.	Yes	**Social cost of carbon:** Used the latest version of the report used in this study to represent the social cost of carbon sequestered by ecosystem assets within the assessment boundary. Care was be taken to ensure the physical and monetary values are in commensurate terms (either carbon or CO_2e, see footnote).
DELWP (forthcoming) Ecosystem services	**Abatement costs**: the study adopts values consistent with scenarios in the Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment Report. IPCC values do not represent actual prices observed from carbon markets, rather they are derived from hypothetical (modelled) abatement	Yes	**Market price / replacement cost:** used IPCC abatement costs under a scenario providing a likely chance of limiting global

[100] A quantity of carbon can be expressed in CO_2 equivalent terms by adjusting for the amount of carbon it contains. The atomic weight of a carbon atom is 12 and the atomic weight of oxygen is 16, so the total atomic weight of CO_2 is 44 (12 + (16 * 2) = 44). This means that a quantity of CO_2 can be expressed in terms of the amount of carbon it contains by multiplying the amount of CO_2 by 0.27 (12/44). e.g. 1 tonne of CO_2 can be expressed as 0.27 tonne of carbon (as this is the amount of carbon in the CO_2) and 1 tonne of carbon can be expressed as 3.66 tonnes of CO_2e (as this is the amount of CO_2 that has that amount of carbon in). (Ecometrica, n.d.).

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Source	Description	Used in Melbourne study?	
from forests in Victoria. Impact of the 2019-20 bushfires	scenarios. Based on a scenario that would provide a likely chance of limiting global temperature increases to below 2°C above pre-industrial levels, the value per tonne of CO2e in 2020 is $71 (in AUD2019).		temperature increases to below 2°C above pre-industrial levels as an upper bound for market prices / replacement cost.
Fairman et al. (2010), Using iTree STRATUM to estimate the benefits of street trees in Melbourne, Victoria	The physical and economic benefits of street trees in a subset of suburbs in Melbourne, Victoria, were assessed in a proof-of-concept of iTree Streets: STRATUM (Street Tree Resource Analysis Tool for Urban Forest Managers), a street tree evaluating model developed by USDA Forest Service. This study uses an economic value of carbon sequestration in Melbourne of $0.033/lb on the basis of a speculative carbon price of $20 dollars / tonne of carbon (1 tonne = 2204.62 lbs so $20/tonne is equivalent to $0.0091/lb, multiplied by 3.66 to get to CO_2e gives a value of $0.033/lb CO_2e). The study estimates the value of street tree carbon sequestration is $7.49 per tree for both Melbourne and Hume on the basis of $0.033/lb CO_2e and the associated carbon sequestration estimates (tonnes CO_2e) from iTree STRATUM.	No	The value is based on a “speculative” price for carbon and therefore is not considered credible for use in the urban Melbourne EEA.
Hope (2006) The social cost of carbon: what does it actually depend on?	This study used PAGE2002, the same probabilistic integrated assessment model as used by the Stern Review, to calculate the social cost of carbon and to examine how it varies with discount rate. It found that the social cost of carbon is not sensitive to the path of emissions on which the tonne of carbon is superimposed. The mean value of the social cost of carbon is $43 per tonne under both a business-as-usual scenario, and under a scenario aimed at stabilising CO_2 concentrations at 550 ppm. The social cost of carbon is sensitive to a number of scientific and economic inputs to the model, with two distributions for the sensitivity of climate to a doubling of atmospheric CO_2 increasing the mean value of the social cost of carbon from $43 to $68 and $90 per tonne. Using a pure rate of time preference of 0.1 per cent per year, as in the Stern Review, gives a mean social cost of carbon of $365 per tonne.	Yes	**Social cost of carbon:** the estimated value from the Hope (2006) study was used in this study as part of a range for the social cost of carbon (along with the latest US Government figures).
Mekala et al. (2015) Valuing the Benefits of Creek Rehabilitation	The precise values adopted in this study are not clear but it states market values for CO_2e have fluctuated from $5 to $14 (no reference given) and that the mean (average) social cost of carbon is approximately $43/tonne under both a business-as-usual scenario, and under a scenario aimed at stabilising CO_2 concentrations at 550 ppm, from a study by Hope (2006) into the social cost of carbon.	Yes	**Social cost of carbon:** the estimated value from the Hope (2006) study was used in this study as part of a range for the social cost of carbon (along with the latest US Government figures).
Moore, G. (2009) Urban Trees: Worth More Than They Cost	This report uses a value of $20 per tonne of carbon (assumed to be CO_2e) based on the value of carbon on the Sydney Carbon Exchange in 2008.	No	This is based on a (now) outdated market price for carbon.

A11.6. Local climate regulation

Table A11.10. provides details on the studies that were considered for use to develop a Melbourne specific assessment of the value of socio-economic benefits associated with the local climate regulating service provided by urban ecosystem assets and how the approaches and data from these studies are proposed for use to inform the Melbourne urban environmental-economic account.

Table A11.10. Review of methods used to estimate the monetary value of avoided health outcomes due to local climate regulation from green and blue space within Melbourne

Source	Description	Used in Melbourne study?	
AECOM (2012) Economic assessment of the Urban Heat Island effect	Estimates the value of morbidity using Department of Health (2012) and the Productivity Commission (2009) (for cost of ambulance services and cost of hospital services respectively) and the value of a statistical life for mortality from the Department of Finance and Deregulation (2008).	Yes	**Value of mortality:** Use the latest value of a statistical life as reported by the Australian Government. **Value of morbidity:** Use the latest value for ambulance attendance from the Department of Health / Ambulance Victoria and the cost of hospital services from the Productivity Commission.
CRCWSC (2019) Estimating the economic benefits of Urban Heat Island mitigation – Economic analysis	Estimates the value of morbidity using Department of Health (2017) (for cost of ambulance services and it is assumed that figures from the Productivity Commission are also adopted for cost of hospital services as per AECOM, 2012 which is quoted in the report) and the value of a statistical life for mortality from the Department of Prime Minister and Cabinet (2015). Productivity is valued using median wage in the case study area (Sunbury) from the 2016 ABS Census. The other socio-economic benefit of local climate regulation that was valued was electricity use which is outside the scope of the preliminary assessment but could be an area for further research.	Yes	**Value of mortality:** Use the latest value of a statistical life as reported by the Australian Government. **Value of morbidity:** Use the latest value for ambulance attendance from the Department of Health / Ambulance Victoria and the cost of hospital services from the Productivity Commission.
NCEconomics (2018) Heatwaves in Victoria: a vulnerability assessment	Estimates the cost to Victoria's economy (by sector and region) of heatwaves is based on reduced Gross Value Added (GVA) presented as Gross State Product and Gross Regional Product.	Yes	**Productivity:** the value of productivity losses will be based on reductions in GVA for the LGA's within the urban area of the assessment boundary.

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A11.7. Recreation

Estimates of the value of socio-economic benefits of recreation within Victoria/Melbourne are set out in Table A11.11.

Table A11.11. Estimates of the value ($) of socio-economic benefits of recreation within Victoria/Melbourne

Socio-economic benefit	Scope	Value	Year	Source
Avoided healthcare costs	Nature-based outdoor activity in Victoria	$265m/yr	2014	MJA (2016)
	Recreation in Victorian Parks	$236m	2014	DELWP & PV (2015)
Welfare	Nature-based outdoor activity in Victoria	$455m/yr	2014	MJA (2016)
	Recreation in Victorian Parks	$0.6-$1bn/yr	2013	DELWP & PV (2015)
Productivity	Nature-based outdoor activity in Victoria	$720m/yr	2014	MJA (2016)
Gross value added (Tourism)	Nature-based outdoor activity in Victoria	$6.2bn/yr	2014	MJA (2016)
	Melbourne park attributable tourism	$433m/yr	2011	Deloitte (2014)
Expenditure	Nature-based outdoor activity in Victoria	$7.2bn	2014	MJA (2016)
Economic contribution[101]	Recreational boating in Port Phillip port	$35.5m/yr	n.d.	DELWP & PV (2015)
	Recreational fishing in Port Phillip port	$24.5m/yr	n.d.	DELWP & PV (2015)
	Recreational tourism in Port Phillip port	$2.25m/yr	n.d.	DELWP & PV (2015)
Employment	Nature-based outdoor activity in Victoria	71,000 FTE	2014	MJA (2016)
	Melbourne park attributable tourism	6,130 people	2011	Deloitte (2014)

Table A11.12. provides details on the studies that were considered for use to develop a Melbourne specific assessment of the value of socio-economic benefits associated with recreational opportunities provided by urban ecosystem assets and how the approaches and data from these studies are proposed for use to inform the Melbourne urban environmental-economic account.

[101] The DELWP and Parks Victoria (2015) report states that these estimates are based on analysis from SKM (2010) and Deloitte Access Economics (2013) and that it includes the value of direct, indirect and induced output and consumer surplus. There could be double counting of value and so these estimates are not deemed to be reliable for use in this Melbourne study but are presented here for purpose of completeness of the literature review.

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Table A11.12. Review of methods used to estimate the monetary value of recreation in urban ecosystems within Melbourne

Source	Description	Used in Melbourne study?	
BDA Group (2015) Valuing the benefits of Victorian waterway management	This study provides estimates of the value of waterway benefits associated with waterway management investments using an ecosystem services framework. Estimates of unit values which are relevant for environmental-economic accounts (i.e. it is the total value of visits not the marginal value of improvements in waterway management to existing visitors) include: i) $40 per visit for incremental waterway visitation at regionally significant sites which is a generalised value based on the available literature from Victoria and NSW to provide an indicative figure for use by CMA's in rural Victoria. It is proposed that this value is used in this Melbourne study (if data on waterway visits exists) to provide an indicative value for waterway recreation in a Victorian urban setting (e.g. River Yarra) but with necessary caveats including that this value has been estimated for regionally specific waterway recreation (not urban) and is based on studies undertaken in NSW; ii) $60 per fishing trip based on a value in Rolfe and Prayaga (2007) which valued recreational fishing at three freshwater impoundments in Queensland (The most conservative value from the study has been used to account for the fact that respondents spent around a week fishing per trip and this is unlikely to be the case in most instances where this value is used for benefit transfer). It is proposed that this value is used in this Melbourne study (if data on fishing in Melbourne's urban waterways exists) to provide an indicative value for recreational fishing in a Victorian urban setting (e.g. River Yarra) but with necessary caveats including that this value has been estimated for NSW.	No	**Welfare:** this study provides estimates for the value of water based recreation in Victoria, although none are developed specifically for the urban environment. Nevertheless, it is proposed that the figures in this study for waterway recreation and fishing are used to provide an indicative figure for the purpose of this preliminary account, with appropriate caveats (see description section) if waterway recreational visits data can be obtained.
Cadilhac et al. (2011) The economic benefits of reducing physical inactivity: an Australian example	Provides dose-response functions linking avoided physical inactivity to health outcomes and costs in Australia. This study is quoted in VicHealth (2016) Physical activity and sedentary behaviour. For example, reducing the prevalence of physical inactivity among Australian adults by 10 per cent would reduce (a) deaths attributed to physical inactivity by 15 per cent per year (b) disability adjusted life years lost by 14 per cent (c) new cases of physical inactivity-related diseases by 13 per cent per year. Reducing physical inactivity in Australia by 10 per cent is estimated to reduce health sector costs by $96 million per year and increase workforce productivity by $12 million (Cadilhac et al. 2011).	No	Although this study provides a potential method to link active recreational visits to improved health and productivity outcomes (assuming a measurement baseline of sedentary activity i.e. without a park these active visits would not occur) there is other information that combines more easily to produce an initial estimate for this study. This information could be considered for use in future iterations of the account.
CRC for irrigation future (2008) Irrigation of Urban Green Spaces: a review of the Environmental, Social and Economic benefits	This study quotes a paper by Maller et al (2002) which estimates the export sales and tourism expenditures related to Melbourne parks and gardens (including bus tours, Melbourne International flower show and Moomba festival). The Maller et al (2002) paper cannot be found (and the CRC (2008) study references two Maller et al (2002) studies so it's unclear which one has the export sale and tourism expenditure figures) to verify the method used to estimate these values and therefore the applicability to this Melbourne study. However, if this study were to be found and GVA estimates were to be included this could be a useful source of evidence.	No	**GVA:** If GVA estimates are to be included in future iterations of the account, consideration should be given to the approach taken/estimates presented in in the Maller et al (2002) study to see how this can be applied to this Melbourne study.
Dedman (2011) Greening the West: a public health perspective	This reference has been mentioned/adopted in various other studies to value the avoided health impacts of park recreation in Melbourne/Victoria but the original source - a Department of Health presentation in 2011 - cannot be found online. However, details of the study are provided where this source is referenced elsewhere (see Mekala et al, 2015 and Frontier, 2019) suggesting that the Dedman (2011) study estimated the cost of a physically inactive person in Australia to be $757 per year. However, it is unclear if this is just avoided medical costs or includes other costs (other sources would suggest that avoided costs are an order-of-magnitude smaller than this).	No	**Avoided cost:** Original source (Dedman, 2011) cannot be found to confirm study details and scope of what's include within avoided cost. Medibank (2008) estimates are used instead as these are used more in the reviewed literature.
Deloitte (2014) Report on Valuing the Tourism Services provided by Victorian Parks	This study was undertaken for Parks Victoria to estimate the economic contribution of park-attributable tourism in Victoria, both in terms of output (Gross Value Added) and employment (people employed). This includes estimates of the economic contribution of Melbourne parks of $433million in 2010-11 using the Melbourne Tourism region as the boundary of the assessment and so will include both "urban" and "non-urban" areas as defined under this study (where estimates for "metro" parks in Melbourne are needed).	No	**GVA:** If GVA estimates are to be included in future iterations of the account, consideration should be given to whether the figures for Melbourne tourism campaign can be used as a basis for estimating the value of urban ecosystem assets within the assessment boundary, as per this Deloitte (2014) study if it can be found.
DELWP and Parks Victoria (2015) Valuing Victoria's Parks	This study uses estimates by Read et al (1999) of the recreational value of different parks/reserves in Victoria ranging from $32 to $9 per visit, including the following which are of relevance to the urban Melbourne EEA region: national parks ($32 per visit), natural features wildlife hunting reserves ($27 per visit), wilderness parks ($20 per visit), port and coastal facilities ($16 per visit), reservoir parks ($14 per visit), natural features reserves ($13 per visit), historic reserves ($12 per visit), State parks ($11 per visit) and other terrestrial parks ($9 per visit). It also uses a value of physical inactivity of $1,660 per person per year (2014 prices) for each physically inactive person (which is $86/person/yr on medical costs, $1,116/person/yr on labour productivity and $458/person/yr on welfare assuming 17.15m people are above 15 years old in Australia in 2008 and	Yes	**Welfare:** Read et al (1999) welfare value of recreation is used. **Productivity and Avoided cost:** Medibank (2008) figures for avoided medical costs (calculated by DELWP

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Source	Description	Used in Melbourne study?	
	56 per cent are physical inactive/sedentary from ABS statistics and uprating for inflation to 2014 values).based on a Medibank (2008) study (the study notes the potential for overlap in these values). The study also includes estimates of the economic contribution (GVA) of coastal recreation, specifically recreational fishing, recreational boating and tourism in Port Phillip port. However, the DELWP and Parks Victoria (2015) report states that these estimates are based on analysis from SKM (2010) and Deloitte Access Economics (2013) and that it includes the value of direct, indirect and induced output *and* consumer surplus. However, it's not clear how these values have been estimated and from the description provided there could be double counting of value. It is not possible to split out these values from the figures provided, so these estimates are not deemed to be reliable for use in this Melbourne study, but are presented here for purpose of completeness of the literature review.		and PV (2015) based on Medibank (2008)) and lost productivity of physical inactivity.
Medibank (2008) The cost of physical inactivity	This reference has been mentioned/adopted in various other studies to value avoided cost of physical inactivity which can be used to estimate the avoided health impacts of recreation in Melbourne's urban ecosystem assets. This includes use/reference in DELWP and Parks Victoria (2015), NCEconomics (2019) and MJA (2016). The study estimates the cost of physical inactivity was costing the Australian economy $13.8 billion per year including medical costs ($719m/yr), labour productivity ($9,299m/yr) and welfare (avoided burden of disease or mortality) value ($3,812m/yr) of avoiding the burden of disease or mortality in 2008. The labour productivity impacts are stated as being a direct cost of $458 per employee per year based on a reduction of 1.8 working days per employee per year. DELWP and Parks Victoria (2015) calculate the marginal value to be $1,660 per person per year for all three socio-economic benefits (which is $86/person/yr on medical costs, $1,116/person/yr on lost GDP and $458/person/yr on welfare assuming 17.15m people are above 15 years old in Australia in 2008 and 56% are physical inactive/sedentary from ABS statistics and uprating for inflation to 2014 values). The larger effect on labour productivity (compared to the $458 estimated by Medibank (2008) is assumed to be because the total effect on GDP is captured (i.e. including indirect and induced effects) rather than just the value of lost labour input.	No	**Welfare:** The Medibank (2008) welfare value of recreation will not be used as there are more relevant estimates to the urban Melbourne context, that cover all visits rather than just "active" visits.
		Yes	**Productivity and Avoided medical cost:** Medibank (2008) figures for avoided medical costs (calculated by DELWP and PV (2015) based on Medibank (2008)), and lost productivity of physical inactivity are used to estimate the value of "active" visits to urban Melbourne EEA region that meet certain physical activity guidelines.
Mekala et al. (2015) Valuing the Benefits of Creek Rehabilitation	Uses value transfer from a Spanish study to estimate the value of a park visit to the community which will not be relevant for Melbourne. Also estimates the avoided cost of physical inactivity from Dedman (2011) which estimates the cost of a physically inactive person in Australia of $757 per year (assuming the number of physically active people in the project catchment increases by 10% to 15%).	No	**Avoided cost:** Original source (Dedman, 2011) cannot be found to confirm study details and scope of what's include within avoided cost.
MJA (2016) Victoria's nature-based outdoor economy	This study estimates regional nature-based outdoor activity Gross Value-Added (GVA, direct and indirect, $ billion) by Tourism Campaign region and by metro. and non-metro. parks in Victoria using input-output models and region specific data on expenditure or population weighted distribution of expenditure by activity. Estimates will include both "urban" and "non-urban" areas as defined under this urban environmental-economic account (for example, the MJA study provides estimates for "metro" parks in Victoria and separately provides estimates for Melbourne, where estimates for "metro" parks in Melbourne are what is needed). Net (adjusted for injury of activity) avoided healthcare costs by recreational activity are also estimated for Victorian parks (walking $4/hr; running, $15/hr; swimming $15/hr and cycling $15/hr) based on an SKM and PwC study for the Queensland Department of Transport and Main Roads (2011) quoted in Department of Infrastructure and Transport (2012) report which estimates of the value of walking and cycling to work (the MJA (2016) study assumes running and swimming are equivalent to cycling in terms of being high intensity activities. It also assumes that the Queensland Government study can be directly transferred to Victoria). These values are high compared to the Medibank (2008) estimates and on consulting the SKM and PwC study for the Queensland Department of Transport and Main Roads (2011) it appears to include both direct ($171.32/person/yr or 8% of total health value) and indirect ($1,941/person/yr or 92% of total health value) costs measured by disability life years which are welfare based values (i.e. measured through individual willingness-to-pay to reduce risk of death). The figures used by MJA (2016) can be adjusted to isolate the direct health benefits of recreation (i.e. 8% of total health costs associated with walking $0.3/hr; running, $1.2/hr; swimming $1.2/hr and cycling $1.2/hr) and welfare (i.e. 92% of total health costs associated with walking $3.7/hr; running, $13.8/hr; swimming $13.8/hr and cycling $13.8/hr) for use in the Melbourne urban environmental-economic account. The study also uses avoided productivity estimates which are based on the Medibank (2008) study (see above) but only uses the direct productivity impacts, not the indirect and induced effects (see Medibank (2008) above). A welfare value for recreation of $50 per day is assumed in the analysis but with little justification and so this is not considered further for use in the Melbourne study.	Yes	**Productivity:** Medibank (2008) figures will be used for productivity costs of physical inactivity
		No	**Avoided cost and welfare:** Information was not available on the type and duration of physical activity undertaken as part of nature-based recreation in urban Melbourne. If this information were available, consideration could be given to using the values developed by MJA (2016) using SKM and PWC estimates for the Queensland Department of Transport and Main Roads (2011). This provides marginal values ($/hr) for direct avoided (medical) costs of physical inactivity and welfare values by activity type that could be applied in this study (noting potential issues of transferring Queensland values ($) to Victoria) if the duration of these activities within the boundary of the account can be estimated, using data or assuming no. hours by activity as per MJA (2016).
		No	**GVA:** If GVA estimates are to be included in future iterations of the account, consideration should be given to whether the figures for Melbourne tourism campaign region can be used as a basis for estimating the value of

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Source	Description	Used in Melbourne study?	
			urban ecosystem assets within the assessment boundary, as per this MJA (2016) study.
NCEconomics (2019) The economic value of open space and urban	Uses recreation values from DELWP and Parks Victoria (2015) of $9 per visit to an urban park in Victoria based on an earlier travel cost study by Reed et al (1999). Estimates the avoided cost of physical inactivity using the approach taken in Mekala et al (2015) which uses Dedman (2011) estimates of the cost of a physically inactive person in Australia of $757 per year. A higher bound estimate for avoided health costs is also developed based on Baumann et al (2008), however this is specifically related to cyclists and so is not proposed for use in this study (although consideration could be given to this in the future if recreation valuation breakdowns by activity type were to be pursued for this Melbourne study). This study also quotes, but doesn't use, the Medibank (2008) study which is used in DELWP and PV (2015)	Yes	**Welfare:** Read et al (1999) welfare value of recreation is used.
		No	**Avoided cost:** Original source (Dedman, 2011) cannot be found to confirm study details and scope of what's include within avoided cost. Medibank (2008) estimates are used instead as these are used more in the reviewed literature.
Read et al (1999) Economic assessment of the recreational values of Victorian Parks.	This reference has been mentioned/adopted in various other studies to value the welfare value of park recreation but the original source - a report for Department of Natural Resources and Environment (April 1999) - cannot be found online. However, details of the study are provided where this source is referenced elsewhere (see NCEconomics, 2019 and DELWP and Parks Victoria, 2015) suggesting that the Read et al (1999) study estimated the recreational value of metropolitan parks in Victoria to be $9 per visit.	Yes	**Welfare:** Read et al (1999) welfare value of recreation will be used.

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Annex 12. Nature-based educational visits by Melbourne suburb

Table A12.1. Suburbs in Melbourne with total school visits to the natural environment in 2019 based on the Victorian Department for Education and Training (DET) Student Activity Locator

Suburb	Visits	Suburb	Visits	Suburb	Visits	Suburb	Visits
Abbotsford	66	Cranbourne	28	Kings Park	4	Ringwood	11
Aberfeldie	0	Cranbourne East	112	Kingsbury	5	Ringwood East	1
Airport West	0	Cranbourne North	12	Kingsville	0	Ringwood North	4
Albanvale	0	Cranbourne South	0	Knoxfield	4	Ripponlea	0
Albert Park	31	Cranbourne West	0	Koo Wee Rup	0	Rockbank	0
Albion	0	Cremorne	0	Kooyong	0	Rokewood	0
Alphington	18	Crib Point	7	Kurunjang	1	Rosanna	5
Altona	48	Croydon	11	Lalor	15	Rosebud	7
Altona Meadows	4	Croydon Hills	0	Lalor West	0	Rowville	2
Altona North	18	Croydon North	0	Lang	0	Roxburgh Park	3
Ardeer	2	Croydon South	0	Langwarrin	15	Rye	23
Armadale	0	Dallas	0	Langwarrin South	0	Safety Beach	10
Arthurs Seat	10	Dandenong	24	Launching Place	1	Sandhurst	0
Ascot Vale	3	Dandenong North	17	Laverton	5	Sandringham	12
Ashburton	14	Dandenong South	0	Laverton North	0	Scoresby	14
Ashwood	1	Deepdene	0	Lilydale	65	Seabrook	0
Aspendale	5	Deer Park	4	Little River	111	Seaford	31
Aspendale Gardens	5	Delahey	0	Lower Plenty	1	Seaholme	3
Attwood	1	Derrimut	0	Lynbrook	1	Seddon	1
Avondale Heights	8	Devon Meadows	0	Lyndhurst	0	Selby	1
Avonsleigh	0	Diamond Creek	4	Lysterfield	101	Seville	0
Badger Creek	95	Diggers Rest	0	Lysterfield South	4	Sherbrooke	23
Balaclava	0	Dingley Village	17	Macleod	27	Shoreham	7
Balnarring	2	Docklands	17	Macleod?	0	Skye	1
Balnarring Beach	3	Doncaster	2	Maidstone	1	Somers	130
Balwyn	3	Doncaster East	25	Main Ridge	2	Somerton	0
Balwyn North	8	Donnybrook	0	Malvern	1	Somerville	0
Bangholme	0	Donvale	0	Malvern East	7	Sorrento	6
Baxter	0	Doreen	6	Maribyrnong	5	South Melbourne	1
Bayles	1	Doveton	90	McCrae	2	South Morang	3
Bayswater	10	Dromana	7	McKinnon	0	South West Sunshine	0
Bayswater North	4	Eaglemont	1	Meadow Heights	3	South Wharf	44
Beaconsfield	5	East Melbourne	10	Melbourne	349	South Yarra	157
Beaconsfield Upper	1	East Warburton	57	Melbourne Airport	0	Southbank	5
Beaumaris	3	Edithvale	18	Melton	25	Spotswood	7
Belgrave	38	Elsternwick	0	Melton South	4	Springvale	14
Belgrave Heights	15	Eltham	30	Melton West	25	Springvale South	8
Belgrave South	1	Eltham North	1	Mentone	0	St Albans	12
Bellfield	8	Elwood	13	Mernda	2	St Andrews	0
Bentleigh	1	Emerald	47	Mickleham	0	St Andrews Beach	1
Bentleigh East	18	Endeavour Hills	2	Middle Brighton	0	St Helena	7
Berwick	30	Epping	2	Middle Park	1	St Kilda	8
Beveridge	0	Essendon	9	Mill Park	1	St Kilda East	1
Bittern	3	Essendon Fields	0	Millgrove	5	St Kilda West	1
Black Rock	15	Essendon North	0	Mitcham	19	Strathmore	2
Blackburn	11	Essendon West	0	Monbulk	1	Strathmore Heights	7
Blackburn North	1	Eumemmerring	0	Mont Albert	0	Sunbury	2
Blackburn South	0	Eynesbury	0	Mont Albert North	14	Sunshine	5
Blairgowrie	9	Fairfield	5	Montmorency	2	Sunshine North	1
Blind Bight	0	Fawkner	4	Montrose	3	Sunshine West	30
Bonbeach	2	Ferntree Gully	84	Moonee Ponds	5	Surrey Hills	0
Boneo	4	Fingal	0	Moorabbin	56	Sydenham	5
Boronia	2	Fitzroy	2	Moorabbin Airport	0	Tarneit	2
Botanic Ridge	1	Fitzroy Island	0	Mooroolbark	9	Taylors Hill	1
Box Hill	0	Fitzroy North	8	Mordialloc	1	Taylors Lakes	7
Box Hill North	0	Flemington	4	Mornington	59	Tecoma	1
Box Hill South	0	Flinders	36	Mount Cottrell	1	Templestowe	9
Braeside	11	Footscray	15	Mount Dandenong	21	Templestowe Lower	1
Braybrook	13	Forest Hill	0	Mount Eliza	9	The Basin	9
Briar Hill	0	Frankston	152	Mount Evelyn	43	The Patch	0
Brighton	11	Frankston North	6	Mount Martha	39	Thomastown	0
Brighton East	0	Frankston South	48	Mount Waverley	19	Thornbury	3
Broadmeadows	11	Garfield	1	Mulgrave	8	Toolern Vale	0
Brookfield	1	Gembrook	24	Murrumbeena	7	Tooradin	1
Brooklyn	0	Gladstone Park	7	Nar Nar Goon	1	Toorak	1
Brunswick	21	Glen Huntly	7	Nar Nar Goon North	0	Tootgarook	3
Brunswick East	185	Glen Iris	3	Narre Warren	5	Tottenham	0
Brunswick West	3	Glen Waverley	9	Narre Warren East	9	Travancore	2
Bulla	0	Glenroy	0	Narre Warren North	12	Tremont	22
Bullarto	0	Gowanbrae	0	Narre Warren South	3	Truganina	9
Bulleen	16	Greensborough	44	Newport	17	Tullamarine	3
Bundoora	162	Greenvale	12	Niddrie	2	Tyabb	0
Bunyip	1	Hadfield	0	Noble Park	5	Tynong	7
Bunyip North	0	Hallam	0	Noble Park North	1	Upper Ferntree Gully	4
Burnley	0	Hampton	0	North Brighton	0	Upwey	1
Burnside	0	Hampton East	12	North Melbourne	39	Vermont	1
Burnside Heights	2	Hampton Park	19	North Warrandyte	2	Vermont South	7

Suburb	Visits	Suburb	Visits	Suburb	Visits	Suburb	Visits
Burwood	6	Harkaway	1	Northcote	4	Viewbank	12
Burwood East	0	Hastings	23	Notting Hill	0	Wallan	0
Cairnlea	12	Hawthorn	2	Nunawading	27	Wandin North	1
Camberwell	7	Hawthorn East	0	Oak Park	0	Wantirna	5
Campbellfield	0	Hazelwood	0	Oakleigh	1	Wantirna South	9
Cannons Creek	0	Hazelwood North	0	Oakleigh East	0	Warburton	43
Canterbury	1	Hazelwood South	0	Oakleigh South	0	Warneet	0
Carlton	8	Healesville	98	Officer	51	Warrandyte	23
Carlton North	24	Heatherton	25	Olinda	23	Warrandyte South	0
Carnegie	0	Heathmont	9	Ormond	0	Warranwood	0
Caroline Springs	23	Heidelberg	32	Pakenham	17	Watsonia	2
Carrum	15	Heidelberg Heights	1	Pakenham Upper	0	Watsonia North	14
Carrum Downs	63	Heidelberg West	15	Panton Hill	0	Wattle Glen	0
Caulfield	1	Highett	3	Park Orchards	0	Werribee	15
Caulfield East	2	Hillside	0	Parkdale	8	Werribee South	295
Caulfield North	0	Hmas Cerberus	0	Parkville	651	Wesburn	86
Caulfield South	16	Hoppers Crossing	6	Pascoe Vale	19	West Footscray	0
Chadstone	0	Hughesdale	6	Pascoe Vale South	1	West Melbourne	35
Chelsea	5	Huntingdale	0	Patterson Lakes	31	West Preston	0
Chelsea Heights	0	Hurstbridge	1	Pearcedale	1	Westmeadows	8
Cheltenham	81	Ivanhoe	1	Plenty	1	Wheelers Hill	119
Chirnside Park	0	Ivanhoe East	0	Plumpton	0	Whittlesea	1
Chum Creek	0	Jacana	24	Point Cook	35	Williams Landing	0
Clarinda	0	Junction Village	0	Point Leo	7	Williamstown	27
Clayton	2	Kangaroo Ground	0	Port Melbourne	8	Williamstown North	0
Clayton South	7	Kealba	3	Portsea	45	Winchelsea	0
Clifton Hill	6	Keilor	20	Powelltown	8	Windsor	1
Clyde	0	Keilor Downs	11	Prahran	1	Wollert	0
Clyde North	0	Keilor East	83	Preston	2	Wonga Park	20
Coburg	22	Keilor North	6	Preston West	0	Woori Yallock	5
Coburg East	0	Keilor Park	1	Princes Hill	0	Wyndham Vale	1
Coburg North	18	Kensington	3	Ravenhall	0	Yallambie	0
Cockatoo	2	Kew	7	Red Hill	0	Yarra Glen	0
Coldstream	0	Kew East	16	Red Hill South	0	Yarra Junction	61
Collingwood	4	Keysborough	58	Research	0	Yarrambat	1
Coolaroo	0	Kilsyth	0	Reservoir	35	Yarraville	3
Craigieburn	34	Kilsyth South	0	Richmond	13	Yarraville	3

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Annex 13. Key uses of urban EEA that were identified from the literature review

Generally, the purpose of the reviewed assessments is to demonstrate the value of urban ecosystem assets to society. The national assessments also serve as preliminary satellite accounts to the System of National Accounts (i.e. GDP accounts) which isolate the economic contribution of the natural environment.

In some instances, the information in accounts is used as a basis for more practical applications, informing policy and planning decisions, including:

- The Natural Capital Account for Greater Manchester was used to identify areas in need of investment in ecosystem assets (eftec et al, 2019). This opportunity mapping combined information on urban ecosystem assets and ecosystem services with environmental quality, social indicators and development areas to identify policy priorities that an investment plan could help achieve. These policy priorities including (a) improved health outcomes (b) improved place (c) resilience to environmental change (d) supporting the local economy (e) conserving and enhancing the local habitat and wildlife (f) sustainable travel (g) water quality and flood management (h) climate regulation and (i) air quality improvement;

- The London Borough of Barnet and Beam Parklands assessments extended the application of natural capital to Corporate Natural Capital Accounting (CNCA). The CNCA framework (eftec, 2015) organises and presents information on ecosystem assets in a similar way to the structured recording of other company assets and liabilities in conventional financial accounts. Corporate natural capital accounts reports the value of ecosystem assets under ownership and the costs (liabilities) of maintaining those assets in a balance sheet format. The CNCA framework can help organisations (both public and private) make better decisions about the natural capital assets that they own and manage.

These UK examples illustrate the importance of considering how an environmental-economic account can be developed for the primary audience, which is DELWP policy colleagues / decision makers for this Melbourne EEA.

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Annex 14. Example of policy relevant analysis using Melbourne EEA

Economic assessment of local climate regulation by green infrastructure in Melbourne in 2051

Summary

- This box summarises an assessment undertaken by the economics team in DELWP's Strategy and Performance division to estimate the economic value of enhanced green infrastructure (tree cover and vegetation) in Melbourne in 2051 that could be delivered through amendments to Victoria's planning policy.
- The assessment builds on the outputs of the bio-physical assessment undertaken by CRCWSC (forthcoming) for DELWP Planning Group and other relevant information and analysis that is specific to Melbourne.
- The partial value of the additional cooling effect that will be delivered by enhanced green infrastructure is estimated to be between ~$1.8 billion and ~$2.8 billion per year (in present value terms) for the Melbourne Metropolitan region in 2051.
- This value predominantly consists of avoided mortality costs (~$1.4billion to ~$2 billion per year) and avoided productivity losses (~$360m to ~$845m per year), but also includes avoided ambulance costs and emergency department presentations which together total between ~$8million and ~$11million per year (in present value terms) in 2051.
- The estimated value provides an indicative estimate of the value of enhancing green infrastructure in Melbourne in 2051 and should be used accordingly (following consultation with DELWP economics team), noting the limitations and uncertainties of the analysis.
- The estimated value is partial because it does not include other socio-economic benefits of green infrastructure's urban cooling such as avoided energy costs, tree deaths, travel delays, tree irrigation, road and pavement maintenance costs and artificial shading.
- The key method steps and uncertainties in the analysis are outlined in Table A14.1.

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Table A14.1. Key method steps and uncertainties

Method step			Uncertainty
Step 1. Estimate the temperature change due to green infrastructure in 2051	Step 1a. Collate information on the extent of Green Infrastructure (GI) features in the geographic area of interest in 2051		Medium
	Step 1b. Apply temperature differential estimates to the extent of relevant GI features in the area of interest in 2051		Very high
	Step 1c. Collate information on current number of days at different temperatures for the area of interest in 2051		High
	Step 1d. Estimate the (fewer) number of days at (more) extreme temperatures under a "with" GI scenario in 2051		Very high
Step 2. Estimate change to socio-economic outcomes due to estimated temperature changes in 2051	2a. Identify estimates of the effect of extreme temperature on socio-economic outcomes in 2051	Adverse health outcomes	High
		Productivity losses	High
	2b. Collate information on the affected population in 2051	Adverse health outcomes	High
		Productivity losses	High
Step 3. Value the estimated change in socio-economic outcomes in 2051		Adverse health outcomes	Very high
		Productivity losses	Very high

- The analysis is highly uncertain, partly because it is assessing socio-economic outcomes in 30 years' time. A key uncertainty in the analysis (very high uncertainty in Table A2) is the approach to converting land surface temperatures to ambient temperatures (Step 1b and 1d). The estimated value of socio-economic outcomes (Step 3) is very highly uncertain due to the combination of uncertainties in the underlying inputs to the calculations.
- The key recommendations for future work to refine this analysis and improve robustness are to (i) develop geographic distribution of the estimated value across Melbourne (ii) identify more up-to-date estimates for some key parameters (iii) identify and apply a wider range of estimates for key parameters as sensitivity analysis to validate the estimated values.

This Annex is structured as follows: Section A14.1. provides background to this analysis, Section A14.2. outlines the role of GI in regulating local climates, Section A14.3. explains the method used to value GI's local climate regulating service in Melbourne in 2051, Section A14.4. presents the results of the analysis, Section A14.5. outlines the assessment's key uncertainties and limitations and Section A14.6. is a short conclusion.

A14.1. Background

The current total socio-economic costs of "extreme heat" in Melbourne (including heatwaves and single hot days over 30°C) are estimated to be significant, as outlined in Table A14.2. These costs include productivity losses to the economy from heatwaves in Melbourne ($53 million per year[102]) and wider costs to the community from extreme temperatures in the City of Melbourne (CBD only[103]) including additional hospital visits and deaths ($79 million per year), energy costs ($5.7 million per year), anti-social behaviour ($4.6 million per year), travel delays ($0.57 million per year), tree deaths ($1.8 million per year) and additional tree irrigation ($0.08 million per year). Table A14.2. shows that the costs of extreme heat are borne by all economic units including the government, communities and businesses.

Table A14.2. Current total estimated socio-economic costs of heat in Melbourne

Impact	Heat type	Economic unit[104]			Spatial area	Cost	Year	Source
		Gov.	*Com.*	*Bus.*		***(2019)***		
Ill health	High temp's	✓	✓	✓	City of Melb.	$79m/yr	Annualised[105]	AECOM (2012)
Productivity	Heatwaves			✓	Melbourne	$53m/yr	2018	NCEcon. (2018)
Energy costs	High temp's	✓	✓	✓	City of Melb.	$5.7m/yr	Annualised[4]	AECOM (2012)
Assaults	High temp's	✓	✓	✓	City of Melb.	$4.6m/yr	Annualised[4]	AECOM (2012)
Tree deaths	High temp's	✓	✓		City of Melb.	$1.8m/yr	Annualised[4]	AECOM (2012)
Travel delays	High temp's		✓	✓	City of Melb.	$0.57m/yr	Annualised[4]	AECOM (2012)
Tree irrigation	High temp's	✓	✓		City of Melb.	$0.08m/yr	Annualised[4]	AECOM (2012)

The costs in Table A14.2. have **not** been aggregated to provide an indicative estimate of the total cost of heat in Melbourne because the costs to the economy (in terms of productivity) are only estimates for specific heatwave episodes (not all high temperatures) and the community impacts focus only on the City of Melbourne (not the wider Metropolitan area). There are also other values missing from Table A14.2. including avoided costs of road and pavement maintenance and artificial shading due to urban cooling. Aggregating these figures would therefore underestimate the total cost of high temperatures to Melbourne's economy and society.

A14.2. Role of green infrastructure (GI) in regulating local climates

The value of GI in urban environments is well established and widely acknowledged. One of the key benefits provided by urban parks, gardens, green roofs, street trees, rivers, lakes and all other GI assets is the "regulation of temperature and humidity, including (through) ventilation and transpiration" (EEA, 2018). The estimated costs to the economy and wider community set out in Section A14.1. (Table A14.2.) would be higher without the existence of current green infrastructure throughout Melbourne because the "local climate regulating" service of these assets would be lost.

It is not known how much higher the costs of high temperatures in Table A14.2. would be without the cooling effect of existing GI in Melbourne as the literature review found no existing analysis estimating this. The economics team

[102] This is the total impact on productivity of heatwaves in Melbourne, whereas the assessment we are undertaking is the marginal impact of additional green infrastructure on high temperatures in 2051 and the associated impact on the economy which is significantly larger in 2051 given economic growth. The NCEconomics (2018) study also took a more nuanced approach to estimating productivity impacts, whereas this study adopted conservative estimates of productivity losses using simple assumptions.

[103] Melbourne CBD is projected to have a population of 216,000 in 2050, whereas Metropolitan Melbourne (the focus of this assessment) will have 8.2million people in 2051. This is a key reason for the discrepancy in the estimated value of heat related ill health in Table A3 and the equivalent value (i.e. for ill health) due to additional GI under the proposed planning amendments as estimated in this study ($104m to $246m).

[104] Whilst there may be other sectors affected by each impact to those noted in Table A3, these are the sectors that have been assessed in the referenced studies.

[105] Annualised values have been calculated using an equivalent annual cost calculation for the present value of costs over the period 2012 to 2051 which have been estimated by AECOM (2012) using a 3% discount rate. This represents the "average" annual cost over the 40 year period, in reality the costs will increase over the period due to population growth and climate change.

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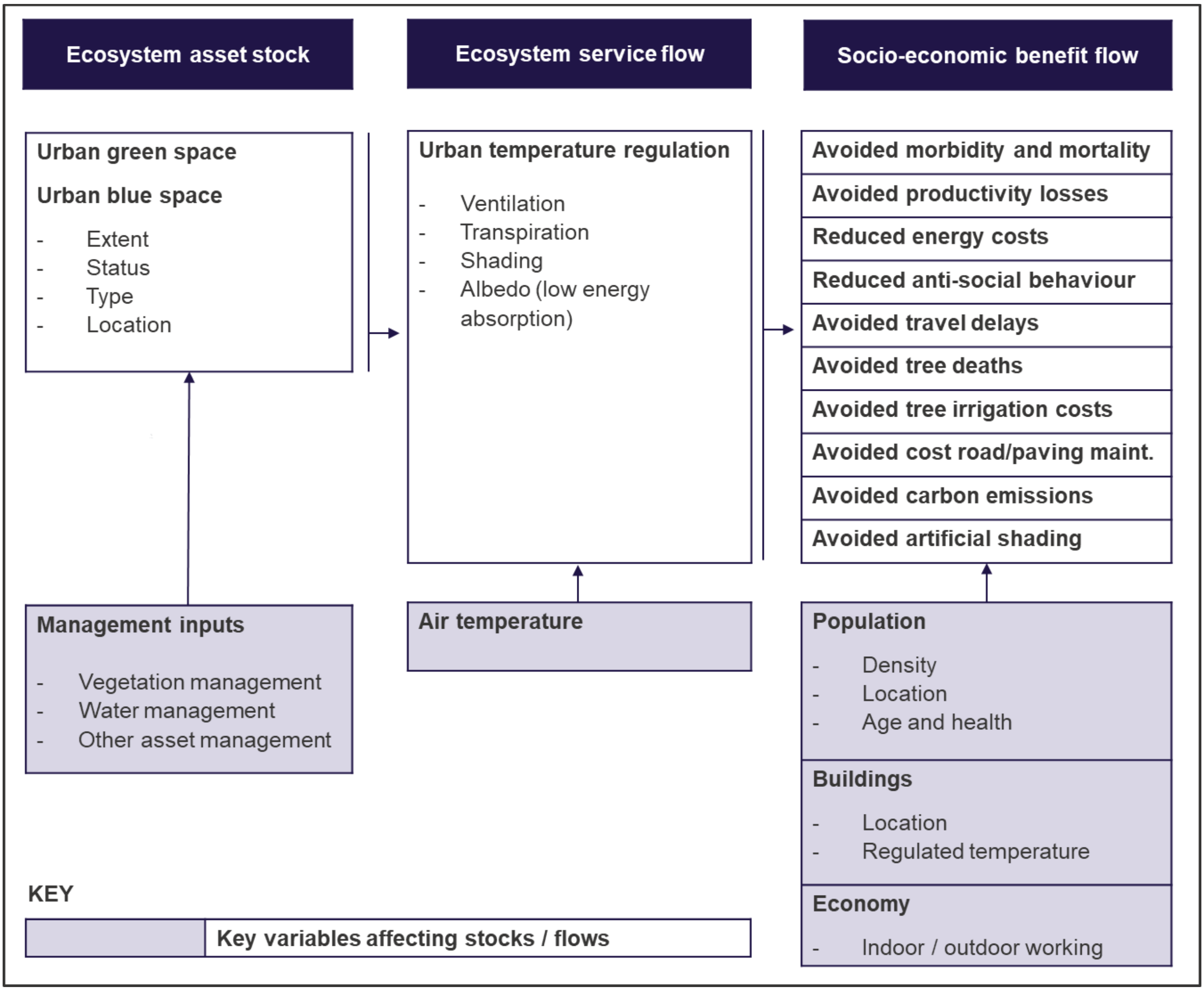
in DELWP's Strategic Performance division are currently working on developing an estimate of this value in line with the UN System of Environmental-Economic Accounts – Experimental Environmental-economic accounts (UN et al., 2012). Figure A14.1. sets out the logic chain linking the ecological functioning of GI assets to the socio-economic benefits provided.

Figure A14.1. Illustrative logic chain for local climate regulating service of green infrastructure



The current socio-economic costs of high temperatures (see Table A14.2.) are likely to increase in the future due to population growth, increased urbanisation (which will intensify the urban heat island effect) and climate change unless careful planning is undertaken to maintain and expand GI in Melbourne.

DELWP commissioned the Cooperative Research Centre for Water Sensitive Cities (CRCWSC, forthcoming) to estimate the value of planning policies and controls that seek to enhance GI (tree cover and vegetation) in Melbourne in 2051 given expected levels of development to accommodate an additional 3.3 million people. This research suggests that the potential amendments to planning policy and development controls will lead to:

- A ~40 per cent (53km^2) expansion in tree canopy cover in Melbourne in 2051, from 142km^2 (under business-as-usual which involves a decline in canopy cover relative to the 2018 base case of 161km^2) to 195km^2;

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- An average estimated reduction in the land surface temperature (°C) in Melbourne in 2051 of 1.3°C (relative to business-as-usual), ranging between a 0.1°C and 3.2°C reduction across Melbourne's Local Government Authorities;

- A 59 per cent (1,037,000 people) reduction in the population exposed to extreme heat in Melbourne in 2051 (out of a projected total of 8.2 million people) under the proposed amendments to the planning system due to the additional GI (leading to an estimated 763,000 people being exposed) compared to business-as-usual (1.8 million exposed).

The remainder of this note explores whether it is possible to use these figures to estimate an economic value for the change in local temperatures (1.3°C) and/or reduced population exposed to extreme heat (~1 million) due to the additional canopy cover (53km^2) in 2051 under the potential amendments to the planning system.

A14.3. Methodology for valuing GI's local climate regulating service in Melbourne

Existing methods to valuing the local climate regulating service of GI from the following sources have been reviewed, including the following sources:

- AECOM (2012) Economic Assessment of the Urban Heat Island Effect;
- NCEconomics (2018) Heatwaves in Victoria: a vulnerability assessment;
- eftec (2017) Scoping and Developing UK Urban Natural Capital Accounts;
- eftec (2018) Scoping UK Urban Natural Capital Account – Local Climate Regulation Extension; and
- CRCWSC (2019) Estimating the economic benefits of Urban Heat Island mitigation – Economic Analysis.

The typical methodological steps (based on the review of the literature and the experience of the study team) to estimate the value of improved socio-economic outcomes of temperature changes due to urban ecosystem assets can be summarised as follows:

Step 1. Estimate changes in temperature due to urban ecosystem assets by combining information on the extent of urban ecosystem assets, prevailing temperatures and estimated temperature differentials due to urban ecosystem assets for the area of interest;

- **Step 2. Estimate changes in socio-economic outcomes due to temperature changes** using estimates of the historical relationship between the incidence of the socio-economic outcome and temperatures (°C) for the geographic area of interest and applying this to estimated change in temperatures due to GI (from Step 1) and the affected population;

- **Step 3. Value the estimated change in socio-economic outcomes** by applying relevant market and/or non-market evidence from the literature to the socio-economic outcome metrics measured in Step 2.

The assessment utilises the outputs of the existing bio-physical assessment undertaken by CRCWSC (forthcoming) to estimate the economic value of planning policies and controls that seek to enhance GI in Melbourne in 2051. For the purposes of this initial assessment, it is proposed that GI's local climate regulating service is valued in terms of its contribution to avoiding the incidence of ill-health (morbidity) and deaths (mortality) and avoided productivity losses only. These socio-economic benefits are expected to provide the greatest value, on the basis that these are currently the highest costs associated with extreme heat in Melbourne (in Table A14.2.).

The remainder of this section provides details on the methodological steps taken to estimate the value of these outcomes, the available sources of evidence (including relevant information from the CRCWSC study (forthcoming)) and results for each step.

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Step 1. Estimate changes in temperature due to GI

1a. Collate information on the extent of GI features in the geographic area of interest

CRCWSC (forthcoming) estimates of total tree canopy cover change under a Green 2051 scenario relative to a BAU 2051 scenario are used. CRCWSC (forthcoming) estimate a ~40 per cent increase (53 km^2) in total tree canopy cover, from 142 km^2 of the total land area of the Plan Melbourne region under the BAU 2051 scenario to 195 km^2 under a Green 2051 scenario.

1b. Apply temperature differential estimates to the extent of relevant GI features in that area

The change in average land surface temperature (LST) reduction across residential zones due to additional GI in 2051 (under Green 2051 compared to BAU 2051) is estimated by CRCWSC (forthcoming) to be 1.3°C. Economic valuation evidence is based on ambient temperatures (not land surface temperatures) and so land surface temperature needs to be converted to ambient temperatures. Al-Gretawee et al (2016) estimated the maximum cooling effect of a park in Melbourne on land surface temperature to be 11.7°C and the equivalent ambient temperature at 5 cm and 1.5 metres above the ground to be 6°C (~50 per cent of LST) and 4.3°C (~35 per cent of LST) respectively. For the purposes of this assessment, to provide an indicative estimate, it will be assumed that changes in ambient temperatures are between 35 per cent and 50 per cent of changes in land surface temperatures based on the Al-Gretawee et al (2016) study. Converting land surface temperature to ambient temperatures using this estimate results in an estimated range of average ambient temperature changes due to the cooling effect of GI under the Green 2051 scenario of between 0.5°C and 0.7°C relative to the BAU 2051 scenario.

1c. Collate information on current number of days at different temperatures for the geographic area of interest

The literature review found information on the expected number of days above 30 degrees in Melbourne CBD in 2050 under the IPCC's A1B emissions scenario[106] (AECOM, 2012) which is used to provide an indicative estimate for this analysis, see Table A14.3.

[106] The IPCC uses a range of GHG emission scenarios, which each provide a different estimate of the future trajectory of GHG emissions. The AECOM study uses scenarios from the 'A1' family which represent a 'high emissions' future, rapid economic growth, a global population that peaks in the middle of the 21st century, and the rapid introduction of new technologies. Current global GHG emissions are tracking in line with this 'high emissions' (A1) future and so it is purported that choosing a set of scenarios which represent a lower emissions future (such as the 'B1' family) would be unduly optimistic (Rahmstorf et al, 2007). A1B is the lowest emissions scenario of the A1 family.

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Table A14.3. Annual number of peak temperature days expected in 2050 under low emissions (AECOM, 2012)

Peak daily temperature (ºC)	Average number of single days per year in Melbourne CBD in 2050 (BAU)
30	48.6
31	43.2
32	36.5
33	30.2
34	25.2
35	19.3
36	13.7
37	11.7
38	9.6
39	5.7
40	4.5
41	2.0
42	1.4
43	0.7
44	0.3
45	0.1

1d. Estimate the (fewer) number of days at (more) extreme temperatures under a “with” GI scenario

For the purpose of this assessment, we require the reduction in number of days at different peak temperatures under a “with” GI scenario in 2051 due to the cooling effect of GI. This has been calculated by applying the temperature differentials of between 0.5°C and 0.7°C (from Step 1b) to the average number of single days at each peak daily temperature estimated under business-as-usual in 2050 (from Step 1c). This application assumed the number of days at each temperature band is evenly distributed within that temperature band and subtracting the temperature differential to the current distribution of single days within that temperature band so that these days move into the previous (cooler) temperature banding. So, if the estimated temperature change was 1°C then *all* the days at each peak temperature would shift into the previous temperature band. For example, under the low estimate of an 0.5°C decrease under a with GI scenario, it is assumed that half the number of days at 31°C will move into the 30°C banding and half the number of days will remain at 31°C. Table A14.4. shows the estimated shift in the number of days towards cooler temperatures under a “with” GI scenario.

Table A14.4. Estimated annual number of peak temperature days with GI in 2051 based on IPCC's A1B emissions scenario (adapted from AECOM, 2012)

Peak daily temperature (°C)	Average number of single days per year in Melbourne CBD			Average *fewer* number of single days per year in Melbourne CBD	
	2050 A1B Emissions	**2051 with Green 2051 scenario**			
		Low estimate (0.5 °C decrease)	*High estimate (0.7°C decrease)*	*Low estimate (0.5 °C decrease)*	*High estimate (0.7°C decrease)*
30	48.6	45.9	44.8	-2.7	-3.8
31	43.2	39.9	38.5	-3.4	-4.7
32	36.5	33.4	32.1	-3.2	-4.4
33	30.2	27.7	26.7	-2.5	-3.5
34	25.2	22.3	21.1	-3.0	-4.1
35	19.3	16.5	15.4	-2.8	-3.9
36	13.7	12.7	12.3	-1.0	-1.4
37	11.7	10.7	10.2	-1.1	-1.5
38	9.6	7.7	6.9	-2.0	-2.7
39	5.7	5.1	4.9	-0.6	-0.8
40	4.5	3.3	2.8	-1.3	-1.8
41	2.0	1.7	1.6	-0.3	-0.4
42	1.4	1.1	0.9	-0.4	-0.5
43	0.7	0.5	0.4	-0.2	-0.3
44	0.3	0.2	0.2	-0.1	-0.1
45	0.1	0.1	0.0	-0.1	-0.1

Step 2. Estimate change to socio-economic outcomes due to temperature change

2a. Identify estimates of the effect of extreme temperature on socio-economic outcomes

Adverse health outcomes

Estimating the effect of extreme temperature on adverse health outcomes typically involves estimating the historical relationship or "dose-response function" between the incidence of human morbidity and mortality and temperatures (°C) for the geographic area of interest (AECOM, 2012). The dose-response functions used in the AECOM (2012) study are set out in Table A14.5. and A14.6. and are based on a published report from Department of Human Services (2009) on the health impacts of the 2009 heat wave in metropolitan Melbourne. All of these functions capture the relationship between a specific measure of ill health and temperatures, measured by number of days above 30°C which provides a link to the information on this that has been developed under Step 1.

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Table A14.5. Information to link the incidence of adverse outcomes to extreme heat in Melbourne

Health outcome		Incidence	Unit
Mortality	Additional mortality due to heat	0.08	Per 100,000 persons per day per 1 degree above 30.0 (AECOM, 2012)
Morbidity	Additional ambulance attendance due to heat related morbidity	0.09	Per 100,000 persons per day per 1 degree above 30.0 (AECOM, 2012)
	Additional emergency department presentations due to heat related morbidity	0.52	Per 100,000 people aged 64-74years, per day per 1 degree above 30°C (DoH in AECOM, 2012)
		3.82	Per 100,000 people aged 74+ years, per day per 1 degree above 30°C (DoH in AECOM, 2012)

Table A14.6. Estimated incidence of adverse health outcomes in 2051 (from AECOM, 2012)

Peak daily temp. (°C)	**Estimated incidence per 100,000 people per day at peak temp's in 2051**			
	Additional mortality (excess deaths) due to heat	Additional ambulance attendance due to heat related morbidity	Additional emergency department presentations due to heat related morbidity	
			64-74years old	74+ years old
30	0.08	0.09	0.52	3.82
31	0.16	0.18	1.04	7.64
32	0.24	0.27	1.56	11.46
33	0.32	0.36	2.08	15.28
34	0.4	0.45	2.6	19.1
35	0.48	0.54	3.12	22.92
36	0.56	0.63	3.64	26.74
37	0.64	0.72	4.16	30.56
38	0.72	0.81	4.68	34.38
39	0.8	0.9	5.2	38.2
40	0.88	0.99	5.72	42.02
41	0.96	1.08	6.24	45.84
42	1.04	1.17	6.76	49.66
43	1.12	1.26	7.28	53.48
44	1.2	1.35	7.8	57.3
45	1.28	1.44	8.32	61.12
46	1.36	1.53	8.84	64.94

Productivity losses

Zander et al (2015) asked people in all Australian capital cities in 2014 whether hot days in the previous two months had affected their work productivity, and by how much. The CRCWSC (2019) study used the original data from this study for Melbourne to estimate a dose-response function linking productivity to different maximum daily temperatures, see Figure A14.2. which shows:

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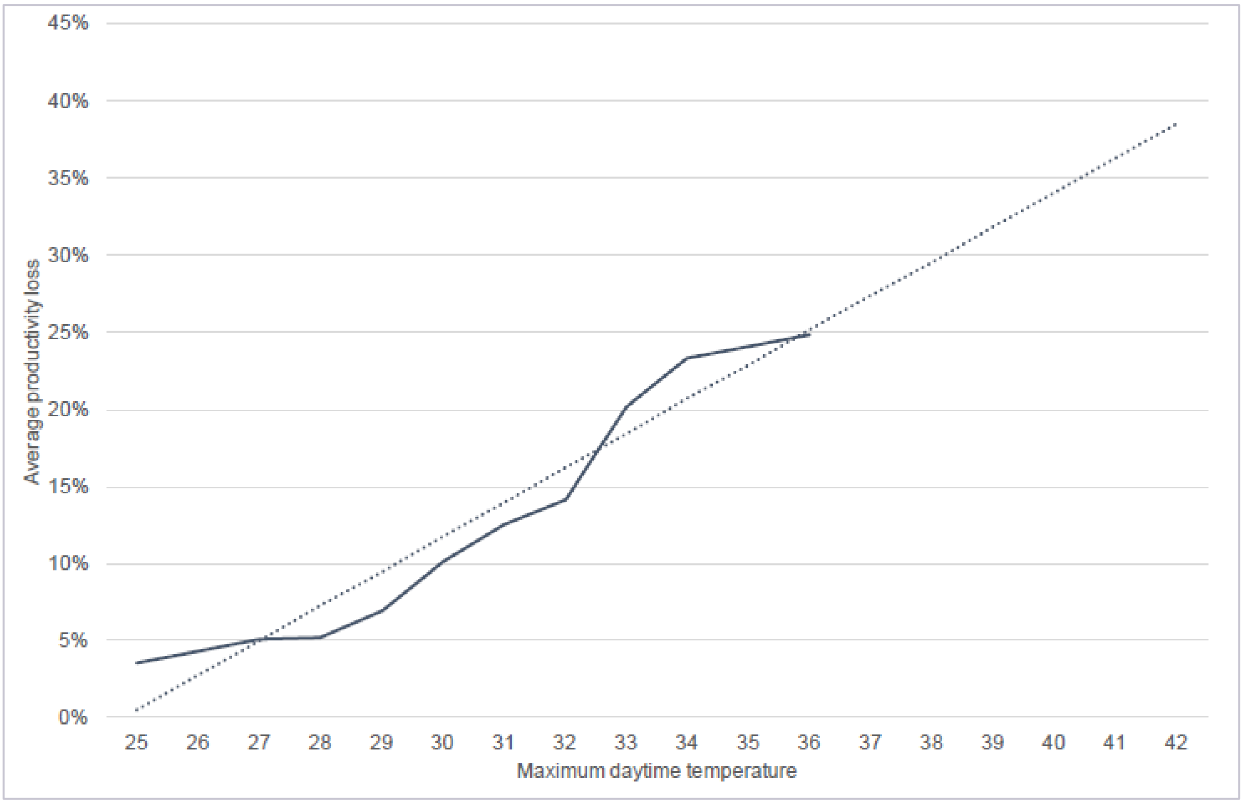
- The loss of worker productivity in Melbourne of daily maximum temperatures is estimated to start at a reduction of 0.6 per cent at 25°C extending to 25 per cent for a 36°C day;
- Given that the survey was undertaken in May and October, no data was gathered for days hotter than 36°C.

For the purpose of this assessment, impacts on productivity will only be estimated for temperatures above 30°C (as this aligns with the readily available temperature data for Melbourne), see Table A14.7. For the purpose of this indicative assessment, the actual data is used for temperatures between 30°C and 36°C and it is assumed that after 36°C the impacts on productivity remain at 25 per cent (rather than using the extrapolated trend line estimated in CRCWSC, 2019).

Table A14.7. Estimated impact of peak daily temperatures on productivity (CRCWSC, 2017)

Peak daily temperature (°C)	Estimated impact on productivity (%)
30	10%
31	13%
32	14.5%
33	20.0%
34	23.0%
35	24.0%
36 to 46	25%

Figure A14.2. Estimated relationship between productivity and maximum daily temperatures (CRCWSC, 2017)



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2b. Collate information on the affected population

Adverse health outcomes

DELWP (2019) estimates of the total Melbourne population in 2051 is 8,464,393 people consisting of 9.5 per cent (802,849 people) aged 64-74 years old and 10 per cent (849,793 people) aged 74+ years. The dose-response functions (from AECOM (2012)) are applied to these total population estimates to estimate the avoided adverse health outcomes under the Green 2051 scenario.

Whilst the CRCSWC (forthcoming) estimate that the presence of additional GI under the Green 2051 scenario will result in 1,037,000 fewer people being exposed to extreme heat due to GI in Melbourne in 2051, this population estimate is not used as the dose-response functions (from AECOM (2012)) are applicable to the total population.

Productivity

The affected population in the case of productivity is the economy of metropolitan Melbourne (DELWP's Port Phillip region). Productivity in metropolitan Melbourne (DELWP's Port Phillip region, see DELWP, 2020) measured through Gross Value Added (GVA) is estimated to be approximately $320 billion in 2018 (REMPLAN Economy, 2020) or $875,000 per day. It is assumed that GVA will increase to 2051 in line with the target for average economic growth of 2.5 per cent, which would mean GVA for Victoria in 2051 would be $722 billion or $2 billion per day.

The CRCWSC (2019) acknowledge that only a proportion of jobs (not the entire economy) will be affected by daytime maximums, either because some will be in air-conditioning or are otherwise unaffected by daytime temperatures (such as evening jobs). In the absence of guidance on this matter, the CRCWSC (2019) study "conservatively assumes (productivity in) 20 per cent of jobs are affected by daytime heat." This crude approach is deemed to be appropriate for the purpose of the assessment, to estimate an indicative value.

2c. Estimate the (avoided) incidence of socio-economic outcomes under the "with" GI scenario

Adverse health outcomes

The total avoided incidence of adverse health outcomes due to the cooling effect of GI in 2051 under a Green 2051 scenario is estimated by applying the incidence rate for different health outcomes per 100,000 people for each day at a peak temperature above 30°C (from Step 2a, see Table A14.5. and A14.6.) to the estimated affected population (from Step 2b) across the number of fewer days at each temperature above 30°C (from Step 1d).

Productivity

This step is not required as impacts on productivity are measured directly through GVA which is a monetary measure, see Step 3.

Step 3. Value the estimated change in socio-economic outcomes

Adverse health outcomes

Table A14.8. sets out the unit values ($ per incident) of adverse health outcomes due to extreme heat in Melbourne from the literature.

Table A14.8. Unit values ($ per incident) of adverse health outcomes due to extreme heat in Melbourne

Health outcome		Value	Unit	Year	Measure	Source
Mortality	Additional mortality (excess deaths) due to heat	$4.9m	$ per incident	2019	Value of statistical life	Dept. of PM and Cabinet (2019)
Morbidity	Additional ambulance attendance due to heat	$1,265	$ per incident	2019	Cost of ambulance	Dept. of Health (2019)
	Additional emergency department presentations due to heat	$4,876	$ per incident	2019	Cost of hospital services	Productivity Commission (2009)

The value of avoided incidences of adverse health outcomes under the "with" GI scenario in 2051 has been estimated by applying the unit values in Table A14.8 to the estimates of avoided adverse health outcomes due to urban ecosystem assets under Green 2051 scenario from Step 2 and discounted to present value terms.

Productivity losses

The avoided cost to productivity due to the cooling effect of GI is estimated by applying the impact on productivity from extreme heat for each day at a peak temperature above 30°C (from Step 2a) to the estimated daily GVA in Melbourne, across the additional number days at each temperature above 30°C (from Step 1d) and discounted to present value terms (at a rate of 3 per cent in order to be commensurate with the AECOM, 2012 figures).

A14.4. Results

Estimated change in socio-economic outcomes due to cooling effect of urban ecosystem assets in 2051

Adverse health outcomes

Table A14.9. shows the estimated total avoided incidence of adverse health outcomes due to the cooling effect of GI in 2051 under a Green 2051.

Table A14.9. Estimated total incidence of ill health avoided due to GI at peak temperatures in 2051

		Estimated total incidence of ill health avoided due to GI at peak temp's in 2051			
		Additional mortality due to heat	Additional ambulance attendance due to heat related morbidity	Additional emergency department presentations due to heat related morbidity	
				64-74 y.o.	*74+ y.o.*
Average ambient temp. changes under the Green 2051	Low estimate (-0.5°C)	-856	-963	-527	-4,102
	High estimate (-0.7°C)	-1,198	-1,348	-738	-5,742

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Productivity losses

This step is not required as impacts on productivity are measured directly through GVA which is a monetary measure, see Step 3.

Estimated value of change in socio-economic outcomes due to cooling effect of urban ecosystem assets in 2051

Adverse health outcomes

Table A14.10. shows the estimated avoided cost of adverse health outcomes due to GI at peak temperatures in 2051 is between ~$1.4 billion and ~$2 billion in 2051 in present value terms. These are discounted at a rate of 3 per cent in order to be commensurate with the values estimated by AECOM (2012) for the City of Melbourne. These are dominated by the avoided mortality due to extreme heat mitigation under the Green 2051 scenario.

Table A14.10. Estimated discounted avoided cost of adverse health outcomes due to GI at peak temperatures in 2051

		Estimated discounted avoided cost ($m) of adverse health outcomes due to GI at peak temp's in 2051				
		Avoided mortality due to heat	Avoided ambulance attendance due to heat related morbidity	Avoided emergency department presentations due to heat related morbidity		Total
				64-74 y.o	*74+ y.o.*	
Average ambient temp. changes under Green 2051	Low estimate (-0.5°C)	$1.4bn	$0.5m	$0.9m	$6.7m	$1.4bn
	High estimate (-0.7°C)	$2bn	$0.6m	$1.2m	$9.4m	$2bn

Productivity

Table A14.11. shows the estimated avoided loss in productivity due to GI at peak temperatures in 2051 is between $363 million and $846 million per year.

Table A14.11. Estimated discounted avoided loss in productivity (GVA $m) due to GI at peak temperatures in 2051

		Estimated avoided loss in productivity (GVA $m) due to GI at peak temp's in 2051
Average ambient temp. changes under the Green 2051	Low estimate (0.5 degrees)	$363m
	High estimate (0.7 degrees)	$846m

A14.5. Key uncertainties and limitations

Table A14.12. outlines the key parameters in each of the methodological steps and provides an uncertainty rating with accompanying explanation for each of these parameters. It also outlines recommendations for the potential refinement of the approach given these uncertainties and the likely effect of this on the results of the analysis. Table A14.12 shows that:

- The adopted methodology relies on existing information for Melbourne, including estimates of:

- Temperature changes due to green infrastructure in 2051 from CRCWSC (forthcoming);
- Changes in socio-economic outcomes using Melbourne specific dose-response functions developed by Department of Human Services (2009), AECOM (2012), Zander et al. (2015) and CRCWSC (2019); and
- The value of these outcomes using literature from the Victorian Public Service on the value of adverse health outcomes and Melbourne's Gross Value Added from ABS data in REMPLAN Economy (2020).

- The analysis is highly uncertain, partly because it is assessing socio-economic outcomes in 30 years' time.

- A key uncertainty in the analysis is the approach to converting land surface temperatures to ambient temperatures which relies on a Melbourne specific study by Al-Gretawee et al (2016). This conversion is necessary to undertake the economic valuation.

- Jobs affected by high temperatures who subsequently have reduced productivity. The estimate relies on an assumption adopted by CRCWSC (2019) that 20 per cent of jobs are affected by daytime heat. However, it is likely that the impacts on productivity are varied across economic sectors and could be substantial where work requires strenuous outdoor activity (e.g. construction) with no air conditioning.

- Some information is over 5 years old and so there is some uncertainty associated with the validity of this information for use in the assessment.

- The estimated value of socio-economic outcomes is very highly uncertain due to the combination of uncertainties in the underlying inputs to the calculations.

Table A14.2. Summary of key parameters and associated uncertainties across the methodological steps

Method step		Key parameters in approach		Uncertainty	Reason for uncertainty rating
Step 1. Estimate the temperature change due to green infrastructure.	Step 1a. Collate information on the extent of GI features in the geographic area.	The ~40 per cent (53km2) expansion in tree canopy cover in Melbourne in 2051.		Medium	The increase in green infrastructure of ~40 per cent forms the basis of the scenario that is being tested (i.e. there is no expectation that this is accurate reflection of reality in 2051).
	Step 1b. Apply temperature differential estimates to the extent of relevant GI features in that area.	Estimate the cooling effect of additional GI in 2051 using the average 1.3°C land surface temp. reduction across residential zones under Green 2051 compared to BAU 2051 estimated by CRCWSC (forthcoming). The analysis does not include the effect of higher future temp's (due to climate change) on the cooling effect of GI.			CRCWSC were specifically commissioned by DELWP to estimate the cooling effect of additional GI. The figure is likely to be conservative as it does not account for the effect of higher future temperatures (due to climate change) on the cooling effect of GI.
		Convert land surface temperatures to ambient temperatures using estimated equivalent temperatures in Melbourne in Al-Gretawee et al (2016) of between 35% and 50% (ambient temperatures as a percentage of LST).		Very high	The adopted approach used the equivalent LST and ambient temperatures in Al-Gretawee et al (2016). The figures are not reported as direct equivalents and only represent "equivalents" at one temp., whereas we might expect the relationship between LST and ambient temperatures to be non-linear.
	Step 1c. Collate info. on current no. days at different temperatures.	Use information on the expected number of days above 30 degrees in Melbourne CBD in 2050 under the IPCC's A1B emissions scenario from AECOM (2012).		High	The figures are directly from AECOM (2012) study, but this is 8 years old and it is not clear how the number of days at each temperature have been estimated using IPCC A1B scenario.
	Step 1d. Estimate the (fewer) number of days at (more) extreme temperatures under a "with" GI scenario.	Estimate the reduction the number of days at different peak temp's under a "with" GI scenario in 2051 due to the cooling effect of GI by assuming the number of days at each temp. band is evenly distributed within that temperature band and subtracting the temp. differential to the current distribution of single days within that temperature band so that these days move into the previous (cooler) temperature banding. So, if the estimated temperature change due to GI was 1°C then all the days at each peak temperature would shift into the previous temp. band.		Very high	The method is considered to be a reasonable representation of the cooling effect of GI in reality, however (as noted above) there is high uncertainty with regard to the robustness of the ambient temperature differentials due to GI.
Step 2. Estimate change to socio-economic outcomes due to temperature change	2a. Identify estimates of the effect of extreme temperature on socio-economic outcomes	Adverse health outcomes	Use information from Department of Human Services (2009) estimating the historical relationship or "dose-response function" between the incidence of human morbidity and mortality and temperatures (°C) for the geographic area of interest, as used in AECOM (2012).	High	The dose-response functions are developed for Melbourne but are over 10 years old so the demographic composition and vulnerability of the population and hence the incidence rate might have changed during that period.
		Productivity losses	Use survey information from Zander et al (2015) on the relationship between hot days and productivity in Melbourne as reported in CRCWSC (2019).	High	The survey was undertaken in the last five years in Melbourne but in May and October, so the impact of temperatures above 36°C on productivity are assumed to remain at 25%.
	2b. Collate information on the affected population	Adverse health outcomes	The affected population in 2051 is estimated using information from DELWP (2019).	High	This is based on DELWP (2019) population projections for 2051.
		Productivity losses	The affected population in the case of productivity is the economy of in metropolitan Melbourne which is measured as Gross Value Added in the Port Phillip region for 2018 using REMPLAN Economy (2020)	High	This is based on Australian Bureau of Statistics information on Gross Value Added, assumed to grow at 2.5% per year to 2051.
			A conservative assumption that 20 per cent of jobs are affected by daytime heat as per CRCWSC (2019).	High	The assumption that productivity effects of high temperatures are only felt in 20% of jobs is crude.
Step 3. Value the estimated change in socio-economic outcomes		Adverse health outcomes	Identify and apply unit values ($ per incident) of adverse health outcomes due to extreme heat in Melbourne from the literature as used in AECOM (2012) to estimates of avoided adverse health outcomes due to GI under Green 2051 scenario and discount to present value terms.	Very high	Estimates of value are from recent publications by VPS departments or agencies, apart from emergency department presentations which is from a Productivity Commission (2009) document that's over 10 years old. The value of a statistical life is a willingness-to-pay estimate (not a market value), which is a conventional approach to valuing avoided deaths in government appraisals. This estimate relies on other information and is assessed as being "very high" uncertainty given the combination of uncertainties.
		Productivity losses	Applying the estimated impact on productivity from extreme heat for each day at a peak temperature above 30°C to the estimated daily GVA in Melbourne, across the additional number days at each temperature above 30°C and discount to present value terms.	Very high	This estimate relies on other information and is assessed as being "very high" uncertainty given the combination of uncertainties.

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A14.6. Conclusion

The partial value of the additional cooling effect that will be delivered by enhanced green infrastructure is estimated to be between ~$1.8 billion and ~$2.8 billion per year (in present value terms) for the Melbourne Metropolitan region in 2051. This value predominantly consists of avoided mortality costs (~$1.4 billion to ~$2 billion per year) and avoided productivity losses (~$360 million to ~$845 million per year), but also includes avoided ambulance costs and emergency department presentations which together total between ~$8 million and ~$11 million per year (in present value terms) in 2051.

The results from this analysis can be compared to existing estimates from the literature on the current total socio-economic costs of "extreme heat" in Melbourne (including heatwaves and single hot days over 30°C), noting the differences in what is being assessed. Current estimates of socio-economic costs of heat include productivity losses to the economy from heatwaves in Melbourne of $53 million per year[107] and wider costs to the community from extreme temperatures in the City of Melbourne (i.e. CBD only[108]) including additional hospital visits and deaths of $79 million per year. These estimates are for the current total costs of heat whereas the policy analysis we have done focuses on the marginal effect of green infrastructure in the future, specifically the year 2051.

Key reasons for the different order-of-magnitude of these figures include that the future analysis accounts for increased temperatures, population and economic output in 30 years and the spatial area differs (i.e. AECOM was only for the City of Melbourne not the Greater Melbourne statistical area).

The future analysis is based on evidence on the expected number of days above 30 degrees in Melbourne CBD in 2050 under the IPCC's A1B emissions scenario (AECOM, 2012) that suggests that there are going to be over 250 days a year of above 30 degree heat in 2050 under a low emissions scenario, including around 10 days of above 40 degree heat. This, combined with the increased population of over 8 million people in 2051, means that there are likely to be a significant increase in the total socio-economic costs of heat in the future. In turn, this means that any intervention that will reduce temperatures (such as additional green infrastructure) will result in greater levels of avoided socio-economic costs and therefore be much more highly valued compared to that intervention occurring today.

The estimated value is partial because it does not include other socio-economic benefits of green infrastructure's urban cooling such as avoided energy costs, tree deaths, travel delays, tree irrigation, road and pavement maintenance costs and artificial shading

The estimated value provides an indicative estimate of the value of enhancing green infrastructure in Melbourne in 2051 and should be used accordingly (following consultation with DELWP economics team), noting the limitations and uncertainties of the analysis.

[107] This is the total impact on productivity of heatwaves in Melbourne, whereas the assessment we are undertaking is the marginal impact of additional green infrastructure on high temperatures in 2051 and the associated impact on the economy which is significantly larger in 2051 given economic growth. The NCEconomics (2018) study also took a more nuanced approach to estimating productivity impacts, whereas this study adopted crude estimates of productivity losses using simple assumptions.

[108] Melbourne CBD is projected to have a population of 216,000 in 2050, whereas Metropolitan Melbourne (the focus of this assessment) will have 8.2million people in 2051. This is a key reason for the discrepancy in the estimated value of heat related ill health in Table A3 and the equivalent value (i.e. for ill health) due to additional GI under the proposed planning amendments as estimated in this study ($104m to $246m).

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References

ABS (2016) Australian Statistical Geography Standard (ASGS): Volume 1 - Main Structure and Greater Capital City Statistical Areas, July 2016

ABS Agricultural Commodities, Australia, 2017-18

ABS Value of Agricultural Commodities Produced, 2018-19

AECOM (2012) Economic Assessment of the Urban Heat Island Effect

AECOM et al (2015) Developing ecosystem accounts for protected areas in England and Scotland. Technical Appendix [Available Online: http://sciencesearch.defra.gov.uk/Document.aspx?Document=13490_DevelopingecosystemaccountsforprotectedareasinEnglandandScotland-TechnicalAppendix.pdf]

Agriculture Victoria (2016) The Victorian Land Use Information System (VLUIS) Metadata description

Aither (2017), Valuing Victoria's Amenities [Made available by Infrastructure Victoria in July 2019]

Al-Gretawee, H., Rayburg, S. and Neave, M. (2016) The cooling effect of a medium sized park on an urban environment. International Journal of GEOMATE, 11(26), pp. 2541-2546

Aurecon (2018) AV / ZEV Environmental & Health Impact Assessment - Final report for Infrastructure Victoria

Australian City Farms & Community Network (n.d.) Directory, Data and Mapping
[Available Online: http://directory.communitygarden.org.au/]

Australian Urban Observatory (2020) Public Open Space [Available Online: Public Open Space - Australian Urban Observatory]

Barton D.N., Caparrós A., Conner N., Edens B., Piaggio M., Turpie J. (2019). Discussion paper 5.1: Defining exchange and welfare values, articulating institutional arrangements and establishing the valuation context for environmental-economic accounting. Paper drafted as input into the revision of the System on Environmental-Economic Accounting 2012 – Experimental Environmental-economic accounting. Version of 25 July 2019.
https://seea.un.org/sites/seea.un.org/files/documents/EEA/discussion_paper_5.1_defining_values_for_erg_aug_2019.pdf

Barton et al (2015) The international OpenNESS project's Oslo case study

BDA Group (2015) Valuing the benefits of Victorian waterway management

BDP et al (2015) Manchester Green Infrastructure Strategy Technical Report [Available Online: http://media.ontheplatform.org.uk/sites/default/files/Manchester%20GI%20Technical%20Report%20FINAL.pdf

Bennett et al (2008) The economic value of improved environmental health in Victorian rivers

Birmingham City Council (2013) Green Living Spaces Plan
[Available Online: https://www.birmingham.gov.uk/downloads/download/208/green_living_spaces_plan]

Unofficial

Brent et al (2016) Valuing Environmental Services Provided by Local Stormwater Management

Broadmeadow, M.S.J. and Freer-Smith, P.H. (1996) Urban Woodland and the Benefits for Local Air Quality, Department of Environment, HMSO, London.

Brooklyn Industrial Precinct (n.d) About [Available Online: http://www.brooklynip.com.au/about/]

Brouwer R., Brander L., Kuik O., Papyrakis E. & Bateman I. (2013) A synthesis of approaches to assess and value ecosystem services in the EU in the context of TEEB. TEEB follow-up study for Europe

Brown (2009) Plan B 4.0: Mobilizing to Save Civilization. Lester B Brown. Chapter 8. Restoring the Earth: Planting Trees to Sequester Carbon [Available Online: http://www.earth-policy.org/books/pb4/PB4ch8_ss3]

Cadilhac et al. (2011) The economic benefits of reducing physical inactivity: an Australian example

Chen et al (2014) Urban vegetation for reducing heat related mortality

Chaplin-Kramer et al. (2019) Global modelling of nature's contributions to people. Science

City of Lancaster (2011) Green Infrastructure Plan

City of London (2011) City of London Green Roof Case Studies [Available Online: https://www.cityoflondon.gov.uk/services/environment-and-planning/planning/heritage-and-design/Documents/Green-roof-case-studies-28Nov11.pdf]

City of Melbourne (2019) Quantifying the benefits of Green Infrastructure in Melbourne. Literature review and gap analysis. [Available Online: quantifying-benefits-green.pdf (melbourne.vic.gov.au)]

City of Melbourne (n.d.) Tree valuation in the city of Melbourne

City of Melbourne (2014) Urban forest strategy – Making a great city greener 2012-2032. Melbourne, Australia

City of Melbourne (n.d.) Valuing Green Guide. Green roods, walls and facades. [Available Online: valuing-green-guide.pdf (melbourne.vic.gov.au)]

Cooper et al. (2016) The Value of Melbourne's Waterways

CRC for irrigation future (2008) Irrigation of Urban Green Spaces: a review of the Environmental, Social and Economic benefits

CRC for Water Sensitive Cities (2017) The climatic benefits of green infrastructure – Industry Note. Cooperative Research Centre for Water Sensitive Cities, Melbourne, Australia

CRCWSC (2017) Review of non-market values of water sensitive systems and practices: An update

CRCWSC (2018) Economic Benefits of Urban Cooling Provided by WSUD

CRCWSC (2018) Economic value of urban heat mitigation

CRCWSC (2019) Estimating the economic benefits of Urban Heat Island mitigation – Economic analysis

Unofficial

Cropper, M. & Khanna, S. (2014) How should the World Bank estimate air pollution damages? – Discussion paper. Resources for the Future

CSIRO et al. (2014) Urban vegetation for reducing heat related mortality

CSIRO and SCION (2006) Commercial Environmental Forestry. Integrating trees into landscapes for multiple benefits [Available Online: https://publications.csiro.au/rpr/download?pid=procite:508b7677-efa7-469f-9c47-84e9d94a9d77&dsid=DS1]

Dedman (2011) Greening the West: a public health perspective

DEE (2017), Ramsar Wetlands of Australia, Department of Environment and Energy, [Available Online: https://data.gov.au/data/dataset/ramsar-wetlands-of-australia]

Defra (2013), 'Air quality: economic analysis', [Available Online: https://www.gov.uk/air-quality-economic-analysis]

Defra (2020) Enabling a Natural Capital Approach: Guidance
[Available online: https://www.gov.uk/guidance/enabling-a-natural-capital-approach-enca]

Defra & GMCA (2016) The Defra urban natural capital pioneer

Defra and ONS (2017) Principles of Natural Capital Accounting
[Available Online: https://www.ons.gov.uk/economy/environmentalaccounts/methodologies/principlesofnaturalcapitalaccounting]

Deloitte (2016) The economic contribution of Melbourne's foodbowl – data is for 2010/11

Deloitte Access Economics (2014), The economic contribution of tourist visitation to Victorian parks [Made available to DELWP]

DELWP (2010), 2010 Index of Stream Condition Scores, [Available Online: https://discover.data.vic.gov.au/dataset/2010-index-of-stream-condition-scores]

DELWP and Parks Victoria (2015) Valuing Victoria's Parks: Accounting for ecosystems and valuing their benefits [Available Online: https://www.forestsandreserves.vic.gov.au/__data/assets/pdf_file/0027/57177/Valuing-Victorias-Parks-Report-Accounting-for-ecosystems-and-valuing-their-benefits.pdf]

DELWP (2016) Marine and Coastal Ecosystem Accounting: Port Phillip Bay [Available online: https://www.environment.vic.gov.au/__data/assets/pdf_file/0025/49813/Marine-and-Coastal-Ecosystem-Accounting-Port-Phillip-Bay.pdf];

DELWP (2016a) Strategic Biodiversity Score [Available Online: http://services.land.vic.gov.au/SpatialDatamart/dataSearchViewMetadata.html?anzlicId=ANZVI0803005827&extractionProviderId=2]

DELWP (2016b) Post Fire Landslide Susceptibility Mapping, Rapid Risk Assessment Teams (unpublished)

DELWP (2017) Native Vegetation Regulation Condition [Available Online: http://services.land.vic.gov.au/catalogue/metadata?anzlicId=ANZVI0803005812&publicId=guest&extractionProviderId=3#tab0]

Unofficial

DELWP (2018) Land use and population research. Urban Development Program

DELWP (2018b) Victorian Forest Monitoring Program
https://www.forestsandreserves.vic.gov.au/forest-management/victorian-forest-monitoring-program]

DELWP (2018c) Designated Water Supply Catchments, [Available online:
https://discover.data.vic.gov.au/dataset/designated-water-supply-catchments]

DELWP et al (2019) Mapping and analysis of vegetation, heat and land use

DELWP (2019), Ecosystem Services from Forests in Victoria: Assessment of Regional Forest Agreement Regions [Available online: https://www.environment.vic.gov.au/__data/assets/pdf_file/0034/459574/Ecosystem-services-from-forests-in-Victoria-Assessment-of-Regional-Forest-Agreement-regions.pdf]

DELWP (2019) Victoria in Future report [Available Online: https://www.planning.vic.gov.au/land-use-and-population-research/victoria-in-future]

DELWP (2019a) Vegetation Cover for metropolitan Melbourne 2018, Cooling & Greening or Vegetation and Urban heat mapping, Plan Melbourne. [Available Online:
http://services.land.vic.gov.au/SpatialDatamart/dataSearchViewMetadata.html?anzlicId=ANZVI0803008494&extractionProviderId=1]

DELWP (2020) CoastKit Resources [Available Online: http://dev-coastkit.cbics.org/]

DELWP (2020a) Place Area Polygon 1:25,000 - Vicmap Features of Interest

DELWP (2020b) Maps and services. Coordinated Imagery Program

DELWP (2020c) Water Area (polygon) 1:25,000 - Vicmap Hydro

DELWP (2020d) Victoria's Land Cover Time series [Available Online: Victoria's Land Cover Time series (environment.vic.gov.au)
Department of the Environment and Energy (2017) Australian Vegetation Attribute Manual Version 7.0 [Available Online: http://www.environment.gov.au/land/publications/australian-vegetation-attribute-manual-version-7]

DELWP (2021) Victorian Biodiversity Atlas
[Available Online: https://www.environment.vic.gov.au/biodiversity/victorian-biodiversity-atlas]

DELWP (2021a) Apiary rights and Bee farm and range licences, Land Management Policy, [Available Online: http://services.land.vic.gov.au/catalogue/metadata?anzlicId=ANZVI0803002141&publicId=guest&extractionProviderId=1#tab0]

DELWP (2021b) Victorian Index of Estuary Condition Score, in production,
https://www.ari.vic.gov.au/research/rivers-and-estuaries/index-of-estuary-condition

DELWP (2021c) Public Land Management (PLM25) [Available Online:
https://discover.data.vic.gov.au/dataset/public-land-management-plm25]

DELWP (2021d) Vicmap Transport Road Network [Available Online:

Unofficial

http://services.land.vic.gov.au/catalogue/metadata?anzlicId=ANZVI0803002595&publicId=guest&extractionProviderId=1

Dept. of Health (2011) The population health impacts of heat Key learnings from the Victorian Heat Health Information Surveillance System;

Department of Health (2017), Ambulance Fee Schedule 2017-18
[Available Online: http://www.health.vic.gov.au/ambulance/fees.htm, ret]

Department of Health (2019) Ambulance Victoria fee schedule 2019-20. [Available Online: https://www2.health.vic.gov.au/hospitals-and-health-services/patient-care/ambulance-and-nept/ambulance-fees]

Dept. Human Services (2009) January 2009 Heatwave in Victoria

Department of Finance and Deregulation (2008) Value of statistical life – Best Practice Regulation Guidance Note, Office of Best Regulation Practice

Department of Infrastructure and Transport (2012) Walking, riding and access to public transport

Department of Prime Minister and Cabinet (2015). Value of Statistical Life, Office of Best Practice Regulation

Dias, S. (2015) The IPBES Conceptual Framework - connecting nature and people

Dickie, I., Cryle, P. & Maskell, L. (2014) UK National Ecosystem Assessment Follow-on. Work Package Report 1: Developing the evidence base for a Natural Capital Asset Check: What characteristics should we understand in order to improve environmental appraisal and natural income accounts? UNEP-WCMC, LWEC, UK. [Available Online: http://uknea.unep-wcmc.org/LinkClick.aspx?fileticket=ALFqJld0K8o%3D&tabid=82]

DISER (2021) Department of Industry Science Energy and Resources, Land Sector Carbon Modelling
https://www.industry.gov.au/data-and-publications/full-carbon-accounting-model-fullcam

DJPR (2003) Acid sulphate soil hazard maps, [Available Online:
http://vro.agriculture.vic.gov.au/dpi/vro/vrosite.nsf/pages/soil_acid_sulfate_soils]

DJPR (2017) Geomorphology of Victoria, [Available Online:
http://services.land.vic.gov.au/catalogue/metadata?anzlicId=ANZVI0803002863&publicId=guest&extractionProviderId=1]

Ducks Unlimited Canada and the Nature Conservancy of Canada (2004) The value of natural capital in settled areas of Canada

DTF (2016) Economic Evaluation for Business Cases Technical guidelines

E2DESIGNLAB (2018) Embedding Green Infrastructure Economic Framework

European Environment Agency (2018) Common International Classification of Ecosystem Services (CICES) [Available Online: https://cices.eu/resources/]

EC (2016) Mapping and Assessment of Ecosystems and their Services. Urban ecosystems. 4th Report.

Unofficial

Ecometrica (n.d.) Greenhouse Gases, CO2, CO2e, and Carbon: What Do All These Terms Mean? [Available Online: https://ecometrica.com/assets/GHGs-CO2-CO2e-and-Carbon-What-Do-These-Mean-v2.1.pdf]

Edens, B, Elsasser, P, Ivanov, E 2019, Discussion paper 6: Defining and valuing carbon related services in the SEEA EEA, paper submitted to the Expert Meeting on Advancing the Measurement of Ecosystem Services for Environmental-economic accounting, New York, 22-24 January 2019 and subsequently revised, version of 15 March 2019.

EEA (2020) CICES. Towards a common classification of ecosystem services [Available Online: https://cices.eu/]

eftec (2009) Valuing Environmental Impacts: Practical Guidelines for the Use of Value Transfer in Policy and Project Appraisal [Available Online: Value_transfer_guidelines_-_full.pdf (publishing.service.gov.uk)]

eftec (2011) Assessing the benefits of learning outside the classroom in natural environments [Available Online: https://ecosystemsknowledge.net/sites/default/files/wp-content/uploads/2013/03/Learning-in-Natural-Environments-report-280211.pdf]

eftec (2015) Beam Parklands Natural Capital Account [Available Online: https://www.london.gov.uk/sites/default/files/beam_parklands_natural_capital_account_final_report_eftec_november_2015.pdf]

eftec et al (2015) Developing corporate natural capital accounts [Available Online: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/516968/ncc-research-cnca-final-report.pdf]

eftec (2015) Applying values in environmental-economic accounting. Discussion Paper [Available Online: http://sciencesearch.defra.gov.uk/Document.aspx?Document=13671_EcosystemAccountingDiscussionPaper_eftec_October2015.pdf]

eftec (2016) London Borough of Havering Green Infrastructure Strategy

eftec (2017) A study to scope and develop urban natural capital accounts for the UK [Available online: http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=19843]

eftec (2018) Natural Capital Account for Greater Manchester [Available Online: https://naturegreatermanchester.co.uk/wp-content/uploads/2018/06/NCA-for-GM-Final-Report-270618.pdf]

eftec et al. (2019) Greater Manchester Natural Capital Investment Plan [Available Online: https://issuu.com/greatermcr/docs/gm-natural-capital-investment-plan-?e=35861904/67415668]

Englart (2015) Climate change and heatwaves in Melbourne – a review

Environment Protection Authority Victoria (2018) Air Pollution in Victoria – A summary of the state of knowledge

EPA (2014) The economic benefits of green infrastructure, a case study of Lancaster, PA

Evangelio et al. (2018), What makes a locality attractive? Estimates of the amenity value of parks for Victoria [Available Online: https://www.infrastructurevictoria.com.au/wp-content/uploads/2019/04/What-makes-a-locality-attractive-Estimates-of-the-amenity-value-of-parks-for-Victoria.pdf]

Unofficial

Fairman et al (2010) Using iTree STRATUM to estimate the benefits. [Available online: https://www.researchgate.net/publication/280721844_Using_iTree_STRATUM_to_estimate_the_benefits_of_street_trees_in_Melbourne_Victoria]

Frontier economics (2019) Health benefits from water centric liveable communities

GLA (2015) Natural Capital Investing in a Green Infrastructure for a Future London [Available Online: https://www.london.gov.uk/sites/default/files/gitaskforcereport.hyperlink.pdf]

GLA (2016) Economic Evidence Base for London 2016 [Available Online: https://www.london.gov.uk/sites/default/files/economic_evidence_base_2016.compressed.pdf]

GLA (2016) The Mayor's street tree initiative

Green Analytics (2016) Ontario's Good Fortune: Appreciating the Greenbelt's Natural Capital

Green Building Council Australia (2018) Building with nature: Prioritising ecology and biodiversity for better buildings and cities

Green Infrastructure Valuation Network (2011) [Available online: https://ecosystemsknowledge.net/green-infrastructure-valuation-toolkit-gi-val]

Griffith University (2020) Economic value of protected areas via visitor mental health. *Nature Communications*.

Hathway, E. A. and Sharples, S. (2012) The interaction of rivers and urban form in mitigating the Urban Heat Island effect: A UK case study. Building and Environment, 58, pp. 14-22

Heris et al (2021) Piloting urban environmental-economic accounting for the United States. Ecosystem Services, 48

Hope, C.W. (2006) The social cost of carbon: what does it actually depend on? Climate Policy 6(5):565–572

Hölzinger, O. (2011) The Value of Green Infrastructure in Birmingham and the Black Country. The Total Economic Value of Ecosystem Services provided by the Urban Green Infrastructure [Available Online: http://www.ukmaburbanforum.co.uk/docunents/other/value_of_green_infrastructure.pdf]

Hölzinger, O. (2015) Birmingham & The Black Country Nature Improvement Area Ecosystem Assessment. The Birmingham and Black Country Nature Improvement Area Partnership, Birmingham. [Available Online: https://ceep-online.co.uk/wp-content/uploads/2018/07/BBC-NIA-EA-2015.pdf]

.id community (n.d.) Demographic resources [Available Online: https://profile.id.com.au/]

Infrastructure Victoria (2018), From Intuition to Evidence: The value of amenity and property prices [Made available by Infrastructure Victoria in July 2019]

Infrastructure Victoria and Aither (2018) What makes a locality attractive? Estimates of the amenity value of parks for Victoria

Intergovernmental Panel on Climate Change (IPCC), Climate Change 2007: Mitigation of Climate Change. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate

Unofficial

Change (Cambridge, U.K.: Cambridge University Press, 2007), pp. 541–84 [Available Online: https://www.ipcc.ch/site/assets/uploads/2018/03/ar4_wg3_full_report-1.pdf]

Jamei, E. and Rajagopalan, P. (2017) Urban development and pedestrian thermal comfort in Melbourne. Solar Energy, pp. 681.

Jayasooriya, V. M., Ng, A. W. M., Muthukumaran, S. & Perera, B.J.C. (2017) Green infrastructure practices for improvement of urban air quality. Urban Forestry & Urban Greening, 21, pp. 34-47

Jones, R. N. and Ooi, D. (2014) Living Brooklyn: Baseline Report on the Economics of the Urban Water Cycle in the Brooklyn Industrial Precinct in Melbourne

Jones, R. N., Symons, J. and Young, C. K. (2015) Assessing the Economic Value of Green Infrastructure: Green Paper. Climate Change Working Paper No. 24. Victoria Institute of Strategic Economic Studies, Victoria University, Melbourne

Jones, L., Vieno, M., Fitch, A., Carnell, E., Steadman, C., Cryle, P., Holland, M., Nemitz, E., Morton, D., Hall, J., Mills, G., Dickie, I. and Reis, S. (2019) Urban natural capital accounts: developing a novel approach to quantify air pollution removal by vegetation. Journal of Environmental Economics and Policy, 8:4, 413-428, DOI: 10.1080/21606544.2019.1597772
[Available Online: https://www.tandfonline.com/doi/full/10.1080/21606544.2019.1597772]

JSA and eftec (2016) London Borough of Barnet Corporate Natural Capital Account [Available Online: https://barnet.moderngov.co.uk/documents/s40941/Appendix%202%20Natural%20Capital%20Account%20for%20Barnet.pdf]

Keith, H, Vardon, M, Stein, J, Stein J & Lindenmayer, D 2017a, Experimental environmental-economic accounts for the Central Highlands of Victoria: Final report, Australian National University Fenner School of Environment and Society, Canberra

Kendal et al. (2016) Benefits of Urban Green Space in the Australian Context

King et al. (2012) Does parkland influence walking? The relationship between area of parkland and walking trips in Melbourne, Australia

kMatrix (2013) London's Low Carbon Market Snapshot – 2013 [Available Online: https://www.london.gov.uk/sites/default/files/london_low_carbon_market_snapshot_-_2013_update_1.pdf]

Lee, K. E. (2015) Gazing at Nature makes you more productive. Defend your research. Harvard Business Review, September, pp. 32-33.

Lee, K. E., Sargent, L., Williams, K., Johnson, K. and Williams, N. (2017) Green micro-breaks: Viewing workplace nature improves mood and performance. in Proceedings of the Seventy-seventh Annual Meeting of the Academy of Management. pp. Online ISSN: 2151-6561.

Lee, K. E., Williams, K. J. H., Sargent, L. D., Farrell, C. and Williams, N. S. (2014) Living roof preference is influenced by plant characteristics and diversity. Landscape and Urban Planning, 122, pp. 152-159.

London Group on Environmental Accounting, 25th Meeting in Melbourne 7th to 10th October 2019

Loughnan et al. (2010) The effects of summer temperature, age and socioeconomic circumstance on acute myocardial infarction admissions in Melbourne, Australia

Unofficial

Loughnan et al. (2013) A spatial vulnerability analysis of urban populations during extreme heat events in Australian capital cities

Mace (2019) The ecology of natural capital accounting. Oxford Review of Economic Policy, Volume 35, Issue 1, Spring 2019, Pages 54–67

Mace, G.M., Hails, R.S., Cryle, P., Harlow, J., Clarke, S.J., 2015. Towards a risk register for natural capital. J. Appl. Ecol. 52, 641–653

Meek, A., Jayasuriya, N., Horan, E. and Adams, R. (2015) Environmental benefits of retrofitting green roofs to a city block. Journal of Hydrologic Engineering, 20(4), pp. 05014020.
Melbourne Water Corporation (2019), Retarding Basin Assets, [Available online: https://data-melbournewater.opendata.arcgis.com/datasets/retarding-basin-assets/explore]

MJA (2014) Valuing the Water Services provided by Victoria's Parks

Marsden Jacob Associates (2016), Victoria's nature-based outdoor economy
[Available online: https://outdoorsvictoria.org.au/wp-content/uploads/2016/03/Outdoor-Economics.pdf]

Mahmoudi et al. (2013), Space matters: the importance of amenity in planning metropolitan growth
[Available online: https://onlinelibrary.wiley.com/doi/full/10.1111/j.1467-8489.2012.00608.x]

Medibank Private (2008), The Cost of Physical Inactivity
[Available at: https://www.medibank.com.au/client/documents/pdfs/the_cost_of_physical_inactivity_08.pdf]

Melbourne City Rooftop Honey (2020) The Project

Mekala et al. (2015), Valuing the Benefits of Creek Rehabilitation: Building a Business Case for Public Investments in Urban Green Infrastructure [Available online: https://www.researchgate.net/publication/274399255_Valuing_the_Benefits_of_Creek_Rehabilitation_Building_a_Business_Case_for_Public_Investments_in_Urban_Green_Infrastructure]

McPherson (2009) Urban Forest Impacts on Carbon, Water and Urban Heat Islands. Center for Urban Forest Research, USDA Forest Service

Moore, G. (2009) Urban Trees: Worth More Than They Cost

Mourato, S., Atkinson, G., Collins, M., Gibbons, S., MacKerron, G., Resende, G., Church, A., Molloy, D., Morling, P., & Pretty, J. (2011) UK National Economic Assessment: Assessment of Ecosystem Related UK Cultural Services
National Capital Commission (2016) Natural capital - The economic value of the national capital commission's green network

NCC (2014) Towards a Framework for Defining and Measuring Changes in Natural Capital [Available Online: Towards a Framework for Defining and Measuring Changes in Natural Capital (publishing.service.gov.uk)]

Natural Capital Project (n.d.) Carbon [Available Online: https://naturalcapitalproject.stanford.edu/software/invest-models/carbon

Natural Capital Project (n.d.) Crop Production

Unofficial

[Available Online: https://naturalcapitalproject.stanford.edu/software/invest-models/crop-production]

Natural Capital Project (n.d.) Recreation [Available Online: https://naturalcapitalproject.stanford.edu/software/invest-models/recreation]

Natural Capital Project (n.d.) Urban Cooling
[Available Online: https://naturalcapitalproject.stanford.edu/software/invest-models/urban-cooling

Natural Capital Solutions (2018) Natural Capital Assessment in Northern Ireland: Urban Study [Available Online: https://www.nienvironmentlink.org/cmsfiles/NI-urban-natural-capital-study---FINAL-2.pdf]

NCEconomics (2018) Heatwaves in Victoria: a vulnerability assessment

NCEconomics (2019) The economic benefits of open space in metropolitan Melbourne: an ecosystem services framework applied in the City of Moreland [Made available by DELWP in September 2019]

Nicholls et al. (2008) A simple heat alert system for Melbourne

Nicholls, N., Loughnan, M., Tapper, N. 2008. A simple heat alert system for Melbourne, Australia. Int J Biometeorology (2008) 52:375–384

Nowak, D.J., McHale, P.J., Ibarra, M., Crane, D. Stevens, J.C. and Luley, C.J. (1998) Modelling the effects of urban vegetation on air pollution, In Gryning, S., Chaumerliac, N. (Eds) Air Pollution Modelling and its Application XII, Plenum Press, New York, 399-407

OECD (2013) Regional, rural and urban development

OECD (2019) Functional urban areas by country [Available Online: https://www.oecd.org/cfe/regional-policy/functionalurbanareasbycountry.htm]

OECD (2012) Mortality Risk Valuation in Environment, Health and Transport Policies (Paris: Organization for Economic Cooperation and Development)

ONS (2018), Value of nature implicit in property prices – Hedonic Pricing Method (HPM) methodology note [Available online:
https://www.ons.gov.uk/economy/environmentalaccounts/methodologies/valueofnatureimplicitinpropertypriceshedonicpricingmethodhpmmethodologynote]

Paddington community garden (2015) How to become a member
[Available online: https://www.paddingtoncommunitygarden.org.au/joining---new-members]

PAE Holmes (2013) Methodology for valuing the health impacts of changes in particle emissions – Final report – prepared for NSW Environment Protection Authority.

Parks Victoria (2015) St Kilda Pier Visitor Monitoring 2015

Parks Victoria (2017), Parks Victoria Annual Report 2016-17 [Available online:
https://www.parliament.vic.gov.au/file_uploads/Parks_Victoria_Annual_Report_2016-17_wM3mLbTJ.pdf]

Parry, I., Heine, D., Lis, E., & Li, S. (2014) Getting energy prices right: From principle to practice. International Monetary Fund.

Unofficial

Payne et al (2015) Adoption Guidelines for Stormwater Biofiltration;

Pearson, L., Tisdell, C., Lisle, A., 2002. The impact of Noosa National Park on surrounding property values: An application of the Hedonic Price Method. Economic Analysis and Policy 32, 155-171

Port Phillip and Westernport Catchment Management Authority (2015) The distribution and abundance of 'blue carbon' within Port Phillip and Westernport, p. 4

Powe, N.A. & Willis, K.G. (2004), 'Mortality and morbidity benefits of air pollution (SO2 and PM10) absorption attributable to woodland in Britain', Journal of Environmental Management, 70, pp. 119–128

Productivity Commission (2009) Performance of Public and Private Hospital Systems. Chapter 5. Hospital and medical costs [Available Online: https://www.pc.gov.au/inquiries/completed/hospitals/report]

Queen Victoria Market (2021) Shop Online [Available at: https://qvm.com.au/] Accessed 13 September 2021

Queensland Department of Transport and Main Roads (2011) Benefits of inclusion of active transport in infrastructure projects, prepared by SKM and PWC

Read et al. (1999), Economic assessment of the recreational values of Victorian Parks [Available online: http://ageconsearch.umn.edu/bitstream/124541/2/Read.pdf]

REMPLAN Economy (2020) Value Added Report

RICS (2015) Planning for Sustainable Land-Use: The Natural Capital Planning Tool (NCPT) [Available Online: http://ncptool.com/Downloads/Planning%20for%20Sustainable%20Land-Use%20-%20The%20NCPT%20Project.pdf]

RMIT (n.d.) Alpine Areas. Building Code of Australia requirements [Available Online: Alpine areas (rmit.edu.au)]

Rolfe and Prayaga (2007), Estimating values for recreational fishing at freshwater dams in Queensland, The Australian Journal of Agricultural and Resource Economics, 51, pp. 157–174

Rossetti (2013), Valuation of Australia's green infrastructure: hedonic pricing model using the enhanced vegetation index [Available online: https://datainspace.org/wp-content/uploads/2017/04/Joe-Rossetti-2013-Thesis-1.pdf]

Royal Botanic Gardens of Victoria (2019) Annual Report 2018-19 [Available Online: rbgv_annual_report_2018-2019pdf.pdf]

SRO (2020) Greater Melbourne and urban zones
Stare, J., (2021) https://www.lightpollutionmap.info/

The Trust for Public Land (2010) The economic benefits of the park and recreation system of Mecklenburg Country, North Carolina

The Clean Air and Urban Landscapes Hub (2019) Air Quality [Available online: https://nespurban.edu.au/research-projects/air-quality/#Extending%20air%20quality%20measurement/monitoring%20capacity]

Unofficial

Thomy et al. (2016), River Health Project Report: The Value of Improving Urban Stream Health in the Cooks River and Georges River Catchments [Available online: https://researchoutput.csu.edu.au/en/publications/river-health-project-report-the-value-of-improving-urban-stream-h]

Tomscha (2019) Background paper Session 4a: Advances in biophysical modelling for environmental-economic accounting. Guidance on Biophysical Modelling for System of Environmental-Economic Accounting (SEEA) Experimental Environmental-economic accounting (EEA)
[Available Online: https://seea.un.org/sites/seea.un.org/files/guidancebiomodellinggc2019_06_18.pdf]

Treeconomics (2015) Valuing London's Urban Forest. Results of the London i-Tree Eco Project [Available Online: https://www.london.gov.uk/sites/default/files/valuing_londons_urban_forest_i-tree_report_final.pdf]

UKNEA (2011) Chapter 22: Economic Values from Ecosystems

UN et al. (2012) System of Environmental-Economic Accounts – Experimental Environmental-economic accounts [Available Online: https://seea.un.org/sites/seea.un.org/files/seea_eea_final_en_1.pdf]

UN et al (2018) SEEA Experimental Environmental-economic accounting Revision 2020. Revision Issue Note – Final. [Available Online: https://seea.un.org/sites/seea.un.org/files/documents/EEA/eea_2020_revision_issue_final_jul2018.pdf]

UN et al (2019) SEEA EEA Revision Expert Consultation Working group 1: Spatial units. Discussion paper 1.2: Treatment of ecosystems assets in urban areas [Available Online: https://seea.un.org/sites/seea.un.org/files/seea_eea_revision_wg1_discussion_paper_1.2_urban_areas_0.pdf]

UN et al (n.d) Technical Recommendations in support of the System of Environmental-Economic Accounting 2012 [Available Online: https://seea.un.org/sites/seea.un.org/files/technical_recommendations_in_support_of_the_seea_eea_final_white_cover.pdf]

UN (2020) System of Environmental-Economic Accounting— Environmental-economic accounting Chapter 13 of the draft document submitted to the Global Consultation on the complete document [Available Online: seea_ea_global_consultation_draft_oct_2020_chapter_13.pdf (un.org)]

UN (2020a) System of Environmental-Economic Accounting 2012 - Experimental Environmental-economic accounting Revision Chapter Draft prepared for Global Consultation. Chapter 7: Accounting for ecosystem services in physical terms [Available Online: 2_seea_eea_rev._ch7_gc_v3.0_jul2020.pdf (un.org)]

UN (2020b) System of Environmental-Economic Accounting 2012 - Experimental Environmental-economic accounting Revision Chapter Draft prepared Global Consultation Chapter 6: Ecosystem services concepts for accounting [Available Online: 2_seea_eea_rev._ch6_gc_v4.0_jul2020.pdf (un.org)

UN (2020c) System of Environmental-Economic Accounting 2012 - Experimental Environmental-economic accounting Revision Chapter Draft prepared for Global Consultation Chapter 9: Accounting for ecosystem services in monetary terms [Available Online: 2_seea_eea_rev._ch9_gc_final_may2020.pdf (un.org)

UN (2020d) System of Environmental-Economic Accounting 2012 - Experimental Environmental-economic accounting Revision Chapter Draft prepared Global Consultation Chapter 8: Principles of valuation for Environmental-economic accounting [Available Online: 2_seea_eea_rev._ch8_gc_final_may2020.pdf (un.org)]

Unofficial

UN (2020e) SEEA EEA Revision: Thematic accounting in the SEEA Available Online: SEEA EEA Revision: Accounting for Ecosystem extent and condition

UN et al (2021) System of Environmental-Economic Accounting—Environmental-economic accounting: Final Draft [Available Online: BG-3f-SEEA-EA_Final_draft-E.pdf (un.org)

University of Melbourne (n.d.) Urban agriculture's role in resilient city food systems [Available Online: https://msd.unimelb.edu.au/research/projects/completed/VEIL/projects/urban-agricultures-role-in-resilient-city-food-systems]

US EPA (2013) The social cost of carbon.
[Available Online: http://www.epa.gov/climatechange/EPAactivities/economics/scc.html]

US Government (2016) Interagency Working Group on Social Cost of Greenhouse Gases 2016, Technical support document: Technical update of the social cost of carbon for regulatory impact analysis – Under Executive Order 12866, United States Government.
[Available Online: https://www.epa.gov/sites/production/files/2016-12/documents/sc_co2_tsd_august_2016.pdf]

Victorian Government (2017) Plan Melbourne 2017 – 2050

VicHealth (2016) Physical activity and sedentary behaviour

Victorian Planning Authority (2019) Metropolitan Open Space Network

Victoria University (2015) Assessing the economic value of green infrastructure: green paper

Vos, E.J., Maiheu, B., Vankerkom, J. & Janssen, S. (2013) Improving local air quality in cities: To tree or not to tree? Environmental Pollution, 183, pp. 113-122

Wise, P. (2014) Grow your own – The potential value and impacts of residential and community food gardening. The Australia Institute – Policy Brief No. 59

World Bank (2019) World Bank's Carbon Pricing Dashboard
[Available Online: http://carbonpricingdashboard.worldbank.org/map_data]

World Health Organisation (2016) Ambient air pollution: A global assessment of exposure and burden of disease

WSP (2013) Melbourne estimation of noise exposure

Zainuddin, Z. & Mercer, D. (2014) Domestic residential garden food production in Melbourne, Australia: a fine-grained analysis and pilot study. Australian Geographer, 45(4), pp. 465-484

Zander, K., Botzen, W., Oppermann, E., Kjellstrom, T. and Garnett, S. (2015) Heat stress causes substantial labour productivity loss in Australia. Nature Climate Change, 5(7), pp. 647-652

Unofficial

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