Final Report

Measuring Urban Green Space in Australia (MUGS)

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The University of Technology Sydney

Project Number: GC15004

GC15004

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Content

Summary

The Hort Innovation Green Cities project “Measuring Australia’s Green Space Asset” (MUGS) undertook a global review of urban green space (UGS) measurement research and engaged with Australian stakeholders to gauge current practice. The overall aim of the project was to foster best-practice UGS planning and management by juxtaposing the scientific state of the art with the contextualised needs expressed by potential Australian end users. The synthesis of findings informed a ‘blueprint’ which sketches the contours of a possible nationally consistent UGS decision-support framework. The framework is illustrated with a worked example from Australia (rapid assessment of urban green space assets using satellite imagery).

Through extensive stakeholder engagement by means of 15 interviews and 5 Focus Groups across Australia we identified strong interest in a nationally consistent UGS decision-support framework. Stakeholder research also found that currently used UGS measures matched the broad thematic grouping of UGS measures found in literature. When synthesising findings these thematic groupings were consolidated in five thematic groups: 1) Human Wellbeing & Liveability; 2) Ecosystem Management; 3) Vegetation Management; 4) Asset Management; and 5) Urban Planning. When current Australian use of UGS measures is compared with the scientific state of the art it can be seen that only a fraction of available measures and associated methods are currently being used. Particularly Human Wellbeing & Liveability measures were under-represented.

The review of scientific literature found two overarching themes: the measurement of *bio-physical* UGS; and the measurement of the *performance* of UGS. Measurement of bio-physical characteristics of green space is particularly important when benchmarking the character of an area under investigation. Bio-physical measures capture such UGS characteristics as: number of trees; tree canopy; number of parks; and size of green space. Bio-physical green space measures provide raw indicators of green space and can be used to inform further metrics. A performance perspective on green space measurement requires defining what performance is. For example, green space can be measured with consideration to biodiversity potential, ecosystem service provision, or recreation benefits. Measuring green space in this way provides more comprehensive assessment of UGS. However, performance-based measures can be more complex to calculate and typically require bio-physical measures. Oftentimes both bio-physical and performance-based UGS measures are necessary.

The project was centred on the notion of “tools”. As there are alternate conceptions of what constitutes a tool it was found that definitional clarity was required before a synthesis of findings could inform the blueprint. Two definitions, as broadly found in literature, were adopted: “soft” tools and “hard” tools. Soft tools are documented/published methodologies of analysis. Hard tools are codified methodologies or software implementations of such methodologies. The project established a catalogue of hard (12x) and soft (6x) tools, each of which was characterised in terms of their ability to map, monitor and report on UGS. The 18 tools were subsequently screened for their potential suitability in the Australian context, and any required modifications were documented. The catalogue of tools is presented below.

Based on findings from stakeholder engagement and literature review, an Australian decision-support framework for best practice UGS planning and management was conceptualised. This reflects an explicit distinction between (existing) analytical *tools* - both “soft” methodologies and “hard” software implementations - and a (novel) decision-making *framework*.

The blueprint employed a storyboard design with six panels, each conveying a key message outlining features of the decision-support framework: 1) growing towards best practice planning and management in Australia; 2) decisions have a variety of entry points; 3) measures are grouped thematically; 4) analytical tools range from published methods to coded software; 5) these elements can be brought together in a decision-support framework; and 6) an example of how the decision-support framework may be used.

Our findings suggest that a nationally consistent decision-making framework would have strong innovative

potential and would stand a high chance of adoption as there is strong demand. A business case would need to be developed to assess the feasibility of implementation.

Keywords

Urban Green Space; Measurement; Measures; Metrics; Methods; Tools; Decision-Support; Ecosystem Services; Natural Assets; Trees; Vegetation; Remote Sensing; Stakeholder engagement; Urban Planning

Catalogue of Urban Green Space Tools

The project established a catalogue of 12 "hard" and 6 "soft" Urban Green Space tools. Using desktop methods, each tool was characterised with respect to its ability to *map*, *monitor* and *report* on UGS. The catalogue includes all tools nominated by interviewees and focus group participants, as well as the tools proposed in the case studies and from literature. Using expert judgment, the research team collectively screened the 18 tools for their potential suitability to be used the Australian context, and required modifications documented. The catalogue is presented below in two tables: an alphabetical list of hard tools (12) and an alphabetical list of soft tools (6).

Legend:

Map = Spatial analysis
Monitor = Temporal/longitudinal analysis
Report = Bio-physical and/or performance characteristics

Alphabetical list of "hard" tools (codified methodologies and/or computer software)

TOOL NAME	MAP	MONITOR	REPORT		SUITABILITY	MODIFICATION	STAKEHOLDERS
			Bio-physical	*Performance*			
ACTMAPi - ACT Land Use database	✓	X	X	X	• ACT only • Fine grained to individual property • Added value of custodianship, developments, roads, heritage sites and licenses	• Extend to all of Australia • Additional measures required (e.g., vegetation management, human wellbeing and liveability, asset management)	• State Government
ArborTrack	✓	✓	✓ • Age • Condition	X	• Proprietary software; not suitable for many users • Manages individual, strands or	• Additional measures required (ecosystem management, human wellbeing and liveability)	• Consultants • Industry • Local Council (used by over 90 UK Councils and 10 International Companies)

TOOL NAME	MAP	MONITOR	REPORT		SUITABILITY	MODIFICATION	STAKEHOLDERS
			Bio-physical	*Performance*			
					groupings of trees over time.		
Coordination of Information on the Environment (CORINE) – Land Use Database	✓	✓	**X**	**X**	• Europe data on land use soil and waste only in aggregated form. • Not applicable to state or neighbourhood scale. • Reduced usefulness for city scale due to resolution	• Classification designed to standardise European reporting on land use change. No specific focus on urban green space • Requires specialist spatial analyst skills	• European Union
Geographic Information System of Cellular Automation using Multi criteria Evaluation - GISCAME - Land Use Database – Case Study #5 (pg 38)	✓	✓	✓ • Vegetation shape • Shannon's diversity index (species diversity) • Patch density	✓ • Focus on aesthetics	• Quantitative landscape metrics-based assessment method of landscape aesthetics	• Primarily used for land planning. • Additional measures required (human wellbeing and liveability, asset management)	• Researchers • Local Government • State Government (Planners) • Education tool
Integrated Open Space Services	**X?**	**X?**	**X?**	**X?**	• Proprietary software; not suitable for many users. Licence Required for	• Reliant on intercept surveys exploring opinions of participation of green spaces, rather than interacting with those	• Consultants • Industry

TOOL NAME	MAP	MONITOR	REPORT		SUITABILITY	MODIFICATION	STAKEHOLDERS
			Bio-physical	*Performance*			
					Access. • Analyses a subset of green space – specifically open space	not using urban green spaces	
i-Tree Suite of Tools **Landscape, Design, Eco, Hydro, & Canopy**	✓	✓	✓ • # trees • Area of canopy • Ecosystem benefits • Carbon Sequestration	✓ • Heat mitigation • Property value	• Heavily resource intensive • Quality highly dependent on consistency of input – both operator and of images • Multi-scale dependent of resolution	• Assumptions not suitable for all end-users	• Consultants • Local government • State Government
Landgate Urban Monitor **(was CSIRO Urban Monitor)**	✓	✓	✓ • Trees • Grass • Veg Index	**X**	• Nationally developed tool, applied specifically in WA. • Possibly moving to proprietary model • Series of base layers available	• Further development to improve for all of Australia • Additional measures required (human wellbeing and liveability, asset management)	• Federal Government • State Government

TOOL NAME	MAP	MONITOR	REPORT		SUITABILITY	MODIFICATION	STAKEHOLDERS
			Bio-physical	*Performance*			
Melbourne Urban Forest Visual	✓	✓ • Tree life expectancy	✓ • Canopy area • Species diversity	X	• Fine scale (individual tree level) • Only for quantifying number of trees and species diversity. No estimation of other metrics. Can be combined with other data sets. • Demonstrates genus and lifecycle	• City of Melbourne only • Extend to include Australia • Additional measures required **(**human wellbeing and liveability and ecosystem management)	• Consultants • Local Government
Neighbourhood Green Space Tool – Case Study #4 (p. 37)	X	X	X	✓ • Access • Recreational facilities • Amenities Natural features • Incivilities • Usage (not used in overall scoring)	• Criteria for assessing the quality of neighbourhood green spaces against a set of indicators (up to a quality score of 100). • Checklist regarding quality, accessibility, recreational facilities, natural qualities, signage, and asset management. • Focus on public	• Spreadsheet format • English example, may need to modify for Australian standards • More likely that this criteria be added into an existing tool	• Currently International, potentially Local Government

TOOL NAME	MAP	MONITOR	REPORT		SUITABILITY	MODIFICATION	STAKEHOLDERS
			Bio-physical	*Performance*			
					rather than private green space		
Sentinel Application Platform (SNAP)	✓	X	X	X	• Platform for processing remote sensing data, including derived vegetation indices. As a tool, can be used for quantifying metrics from remote/satellite data. • Requires advanced expert knowledge.		• Consultants • State government
Urban Atlas – European Environment Agency	✓	✓	✓ • Land use • European Environment Agency Indicators	X	• Europe only • Includes urban green space category within broader land use database. See also CORINE) • Up to 1m resolution (city scale) • Comparable land use and land cover for zone with more than 100,00 inhabitants as	• Extend to include Australia • Additional measures required	• Pan-European

TOOL NAME	MAP	MONITOR	REPORT		SUITABILITY	MODIFICATION	STAKEHOLDERS
			Bio-physical	*Performance*			
					defined by the "Urban Audit" • Only contains small number of land use classes (e.g., green space) • Questionable robustness of derivation of land use classes		
Victorian Land Use Information System (VLUIS)	✓	**X**	**X**	**X**	• Vic only • Focus on primary production – spatial dataset on land tenure, land use and land cover for each cadastral parcel in the state of Victoria.	• Extend to include Australia • Additional measures required	• State Government

Alphabetical list of "soft" tools (documented methodologies of analysis)

TOOL NAME	MAP	MONITOR	REPORT *Bio-physical*	*Performance*	SUITABILITY	MODIFICATION	STAKEHOLDER
NSW Office of Environment and Heritage - Urban Green Cover Technical Guidelines	X	X	X	X	• Guidance document	• National policy guidelines yet to be implemented	• Consultant • Local Government • State Government • Federal Government • Industry
Department of Planning WA - Liveable Neighbourhoods	X	X	X	X	• Policy document	• National policy guidelines yet to be implemented	• Consultant • Local Government • State Government • Federal Government • Industry
Environmental quantitative assessment of urban parks Case Study #1 (p. 35)	X	X	X	X	• Methodological approach to in situ measurements of climatic, air pollution and noise variables. • Data scaling possible for comparisons	• Does not include elements of quality of vegetation. • Additional measures required	• Consultant • Local Government
Metric of effective green equivalent (EGE) Case Study #3 (p. 36)	X	X	X	✓ • Accessibility (as a proxy for performance) derived from Normalised Difference Vegetation	• This measure of public green space does not include residential green space.	• More likely that this criteria be added into an existing tool	• Consultant • Local Government

TOOL NAME	MAP	MONITOR	REPORT *Bio-physical Performance*		SUITABILITY	MODIFICATION	STAKEHOLDER
				Index (NDVI)			
Public Open Space Desktop Auditing Tool	**X**	**X**	**X**	**X**	• Survey pro forma document only	• Requires implementation (online) • Subjective tool • Additional measures required • Further verification of methods required	• Consultant • Local Government
Urban Neighbourhood Green Index **Case Study #2 (p. 36)**	✓	**X**	**X**	**X**	• Neighbourhood scale • Tool relies on complicated analysis and data sets • Explores green space in regards to population growth • Uses satellite data	• More likely that this criteria be added into an existing tool	• Consultant • State Government • Federal Government • Industry

List of Acronyms

Acronym	Description
AHP	Analytic Hierarchy Process
ASGC	Australian Standard Geographical Classification
ASGS	Australian Statistical Geography Standard
CORINE	Coordination of Information on the Environment
EVI	Enhanced Vegetation Index
EVI2	Two-band Enhanced Vegetation Index
GIS	Geographic Information System
GISCAME	GIS= geographic information system, CA = cellular
IOSS	Integrated Open Space Services
LIDAR	Light Detection and Ranging
LGA	Local Government Authority
MCDA	Multi-criteria decision analysis
MODIS	Moderate Resolution Imaging Spectroradiometer
MUGS	Measuring Urban Green Space
NGST	Neighbourhood Green Space Tool
NSW	New South Wales
NDVI	Normalised Difference Vegetation Index
OSAMP	Open Space Asset Management Plan
PAG	Project Advisory Group
POS	Public Open Space
POSDAT	Public Open Space Desktop Auditing Tool
QLD	Queensland
SA	South Australia
SNAP	Sentinel Application Platform
UC/L	Urban Centres and Localities
UGS	Urban Green Space
UHI	Urban Heat Island
VIC	Victoria
WA	Western Australia

1. Introduction

The Hort Innovation Green Cities project "Measuring Australia's Green Space Asset" (GC15004) undertook a review of current and emerging approaches, models and tools (methods) that may be employed in Australia to characterise, benchmark and monitor urban green space (UGS) assets in Australia's urban environments. The review comprised extensive stakeholder engagement (interviews and focus groups) and a comprehensive review of the scientific literature.

The overall project aim was to foster best-practice UGS planning and management by juxtaposing the **scientific state of the art** with the **contextualised needs** expressed by potential Australian end users. The resulting 'blueprint' sketches the contours of a possible **nationally consistent UGS decision-support framework.**

1.1 Research questions

The project asked the following three research questions:

Research question 1: What are the current practices of UGS measurement in Australia?

- Who is managing and planning for UGS?
- What methods and measures are currently being used?
- What are the most common use situations?

Research question 2: What is the current scientific state of the art with respect to UGS measurement?

- What methods and measures have been researched and are being recommended?
- What 'tools' (frameworks, approaches, platforms) currently exist?

Research question 3: What coherent decision-support framework could foster best practice UGS planning and management in Australia?

- What characteristics would such a framework need to have in order to shift practice?
- What characteristics would such a framework need to have to maximise the likelihood of broad adoption?

Whilst the research deliberately refrained from adopting *a priori* definitions of urban green space, our starting point was both public and private horizontal open and green space in urban and peri-urban areas.

An extensive stakeholder engagement phase canvased current practice and user needs with respect to the measurement of Australia's green space assets. This research task corresponded to our brief to "consult widely with end users from the outset, including local councils, to ensure the recommended mapping tool meets the needs of those who will use it".

A targeted review of the international scientific literature elicited the scientific state of the art and identified relevant global examples. This research task corresponds to our brief to: "identify the existing tools available globally that are used to map, monitor and report on green space".

Findings from these two research activities, which were conducted in parallel, have informed a 'blueprint' for a generic UGS decision-support framework that could foster best-practice UGS planning and management in Australia. The blueprint references a worked example (satellite mapping) developed by the project team. The 'blueprint' consolidates a nationally consistent approach for the measurement of Australia's green space asset. This approach addresses the diverse needs of a wide range of Australian users; reflects international state-of-the art approaches for measuring UGS, and has strong potential for innovation.

1.2 Tools for Measuring UGS

The MUGS project is centred on the notion of "tools". There are alternate conceptions of what constitutes a "tool". This section offers definitional guidance.

What is a tool? The Oxford English Dictionary (OED) defines a tool as:

> *a device or implement, especially one held in the hand, used to carry out a function; a thing used to help perform a job*

For the purpose of this project, two definitions broadly found in literature have been adopted: **"soft" tools** and **"hard" tools**.

Soft tools are tools more akin to **methodologies of analysis**. An example is offered by Gidlow et al (2012), who developed a tool for assessing quality of neighbourhood green space in Staffordshire, UK (the **Neighbourhood Green Space Tool**; see also Case Study #4 in Section 3.2.3 Case Studies. This methodology is developed from stakeholder engagement and assessment of other tools which are reviewed in their paper. The tool developed by Gidlow et al (2012), and the tools reviewed, primarily "codify" UGS measures to be used in the assessment of some domain of UGS (in the case of Gidlow et al (2012) the domain is quality). In an Australian context, the **Public Open Space Desktop Auditing Tool (POSDAT)** (Edwards et al., 2013) is a soft tool for measurement and quality assessment of public green space in Perth. The tool provides a large set of indicators which the tool user can compare against to determine green space quality.

We can describe such methodologies of analysis as "soft" tools - what is actually developed is a methodology for appraisal of green space indicators. Such methodologies are highly context-dependent and often their relevance may be limited to the area under investigation. Tools such as POSDAT (Edwards et al., 2013) are often described as a "tool" - but such tools are not readily applicability to other jurisdictions in Australia without further assessment and major tweaking. It is important to note that the vast majority of the reviewed literature made use of methodologies similar to these "soft" tools. Therefore, we consider these "soft" tools having importance in the development of a blueprint of a tool for the Australian context – they provide a means of organising and appraising applicable indicators for domains of UGS evaluation.

Hard tools are tools both more readily applied to arbitrary areas/scales, and that can be used to quantify indicators and metrics more directly. A primary example of a "hard" tool that was identified in focus groups was *iTree*, a desktop GIS tool whereby practitioners provide a study area, and through random sampling and visual inspection can derive estimates for vegetation cover. Other such hard tools include remote sensing platforms such as Sentinel application platform (SNAP), Coordination of Information on the Environment (CORINE), and Urban Atlas, where some metrics (for example, vegetation indices) are readily provided, or can be estimated through further processing and analysis.

The advantage of "hard" tools over "soft" tools is that hard tools can provide the raw metrics and indicators used in the assessment and measure of UGS (for example, number of parks, proportion vegetation coverage, etc.). It may certainly be the case that tools such as *iTree* would be required to be used in "soft" tools as well, for example, if proportion of tree canopy coverage is required. Disadvantages of "hard" tools are present, however, in that some require varying levels of expert knowledge (for example advanced knowledge of sensor systems and image classification is required for example to extract metrics from SNAP data). This is not strictly true for all hard tools, for example Urban Atlas contains estimates for proportion of vegetated land cover, however, is only applicable for the EU.

The benefit of comparing both soft and hard tools is that there is a clear desire and need for tools that can readily be applied to measuring green space indicators as provided by soft tools, but hard tools enable such soft tools to be applied. This is true for soft tools that do require bio-physical data, and may not be true for tools where bio-physical data is not required.

1.3 Structure of this report

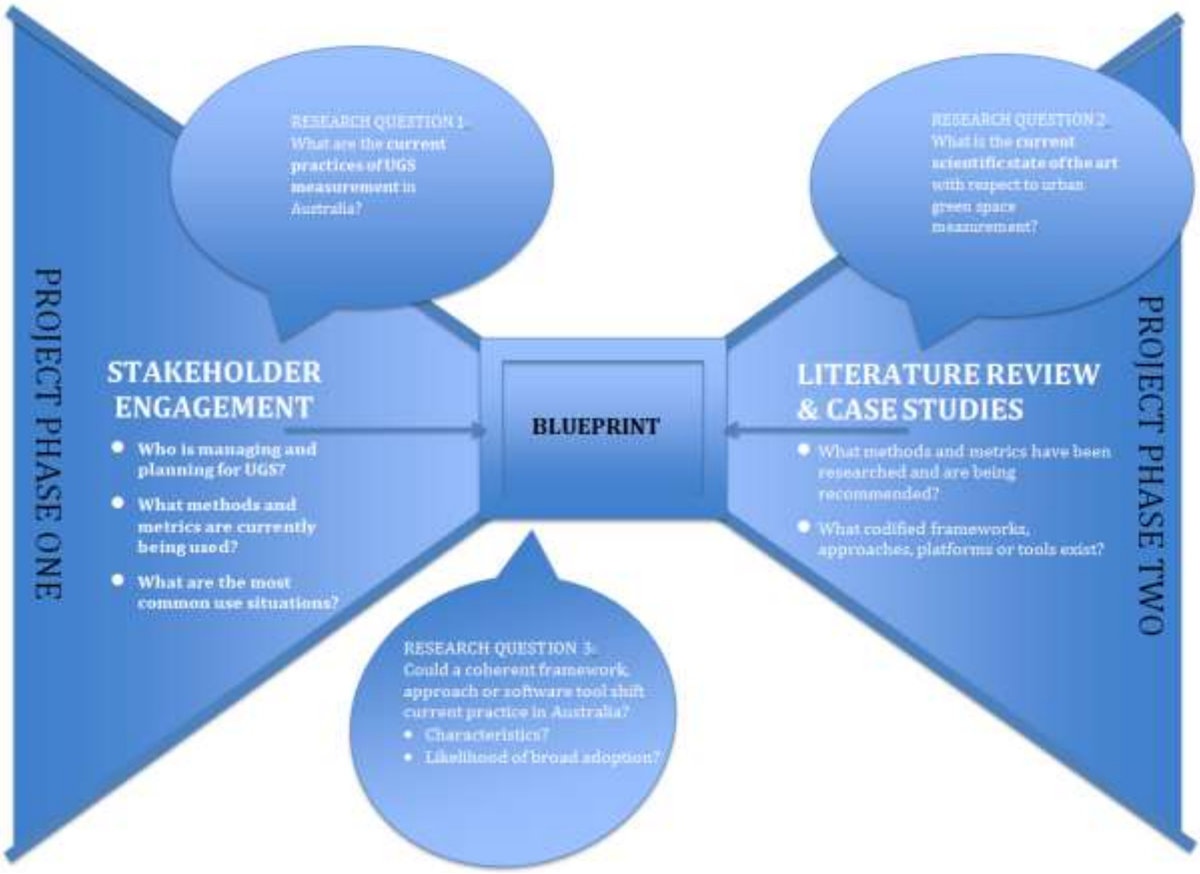
Chapter 2 below details the overall methodology and methods used to gather data and review literature. Chapter 3 presents findings in three subsections: stakeholder engagement; literature review and case studies; and blueprint development. Chapter 4 briefly discusses outcomes whilst Chapters 5 and 6 offer discussion and recommendations.

2. Methodology

Figure 1 below shows the rationale of the MUGS project. On the one hand (left hand side; research question 1), stakeholder engagement across a range of potential users elicited who are managing and planning for UGS in Australia; what methods and measures are currently being used; and what the most common use situations of these methods and measures are. On the other hand (right hand side; research question 2), a comprehensive review of the scientific literature to reveal what methods and measures have been researched to date and which methods and tools can be considered best practice.

The juxtaposition of findings from these two efforts framed the contours of a nationally consistent Australian approach for measuring UGS (research question 3), resulting in a 'blueprint' for a best-practice decision-making framework. In the context of the MUGS project, a 'blueprint' is defined as a design plan, or technical drawing.

Figure 1 Project rationale



The project rationale is reflected in the project design, consisting of three Phases:

Phase I (*Preparation*) involved consulting widely with potential end users to ensure the recommended method will meet the users' needs. This has been completed through

- 15 telephone interviews of 20 minutes' duration with stakeholders nationally;
- 5 focus groups conducted in New South Wales (NSW), Victoria (VIC), South Australia (SA), Western Australia (WA) and Queensland (QLD).

Phase II (*Review*) involved a detailed literature review and case studies from cities around the world.

Phase III (*Dissemination*) disseminated the project's findings in the form of a blueprint for an Australian best-practice decision-support framework for UGS planning and management.

A Draft Technical Report, the deliverable under project Milestone 2.1 ("*Draft Technical Report on findings from literature review and evaluation/screening of metrics*") was delivered to Hort Innovation in May 2017. This report is the final version of the draft report and presents the findings from all phases of the project and is a deliverable for the final milestone of the project (Milestone 3.1 *"Final Technical Report and delivery of industry/community presentation"*).

Dissemination of the research findings will occur beyond the timeframe of Milestone 3.1, where the research team will present the MUGS project and its resulting blueprint at two major industry conferences attended by key stakeholders: the EcoCity World Summit in Melbourne (July 2017) and the 10th Making Cities Liveable Conference in Brisbane (July 2017).

This project used a range of qualitative and quantitative methods to explore the academic literature for best practice cases of urban green spaces methods and tools; identify Australian stakeholder practices and needs; identify best practice examples from around the world; and develop an original worked example for Australia.

The remainder of this section explains the methods used during the three phases of research – Phase I: *Interviews and Focus Groups*; Phase II: *Literature Review and Case Studies*; and Phase III: *Developing a 'blueprint' and dissemination.*

2.1 Interviews

Stakeholders were selected through a snowball sampling technique (Biernack & Waldorf, 1981). This non-probability sampling technique, which is commonly used in social research, involves working with existing study subjects to recruit future subjects from among their acquaintances. Stakeholders identified through snowballing were selected for telephone interviews based on the following criteria:

- Involved in urban green space planning from industry, state or local government;
- Experienced with, or interested in, existing and potential urban green spaces in Australia;
- Involved in measuring (including mapping), regulating, developing or promoting urban green space projects;
- Able to provide perspectives on urban, peri-urban and suburban green spaces nationally;
- Representative of disciplines involved in green spaces such as urban planner, horticulturalist, ecologist, scientists, geospatial analyst, GIS specialist, landscape architect, health professional, policy-maker and public servant.

A total of 15 telephone interviews were undertaken within this phase (duration approximately 20 minutes each) with national stakeholders. For a full list of procedures and interviewees, please refer to Appendix A and Appendix C.

2.2 Focus Groups

Upon completion of their interviews, interviewees were asked if they would be willing to take part in a half-day focus group. They were also asked to refer other participants, thus continuing the snowball sampling. A total of five focus groups were then conducted in NSW, VIC, SA, WA and QLD. The focus group activities included listing of UGS measures and affinity mapping to identify thematic groupings of measures. This was followed by a group discussion of use situations (decisions requiring measurement of UGS), and a potential national framework for UGS measurement. For the full procedure of focus group activities, please refer to Appendix B and Appendix D.

2.3 Literature Review

A comprehensive review of academic literature was conducted by surveying the following academic databases:

- Elsevier ScienceDirect;
- Scopus;
- ISI Web of Science.

Literature was collected based on the following search terms:

- "URBAN GREEN SPACE INDICATORS | METRICS"
- "URBAN ECOSYSTEM SERVICES INDICATORS | METRICS"
- "MEASURING URBAN GREEN SPACE | ECOSYSTEM SERVICES"

The term "METRICS" rather than "MEASURES" was used as the latter search term was deemed too general for the purpose of querying databases. Appropriate search results were stored in an EndNote database. Bibliographies in the literature collected were subsequently surveyed to identify further potentially relevant literature for collection and review. Once collected, the literature was grouped into the below themes by focus of the study. These focal themes were used as subheadings in an annotated bibliography (Appendix I). The themes characterise the *general* focus of the research, rather than an attempt to classify the measures used, which was done at a later stage.

1. **Ecosystem services based measures** – for this review, ecosystem services are defined as the supporting, provisioning, and regulating services provided by ecosystems. This category covers such services as nutrient recycling, carbon sequestration, and air purification[1].
2. **Quality-based measures** – here, quality refers to the quality of green space under investigation. Quality can include such aspects as species diversity, quality of amenities, and vegetation coverage for green spaces.
3. **Accessibility-based measures** – accessibility refers to both bio-physical and socioeconomic aspects of accessibility, for example, physical proximity to green space, and proximity of green space for poor neighbourhoods.
4. **Urban design and planning-based measures** – these include aspects of urban design and planning such as benefits for local property values, and incorporating green space into local town planning ordinances, in addition to indicators related to transportation.
5. **Public health and recreation-based measures** – these include aspects of public health and recreational benefits of green space.

Papers were reviewed in the above themes to clarify methods and techniques used for the establishment of UGS measures. Furthermore, how UGS measures were applied was reviewed and any other findings that could inform the MUGS project noted. All measures found in the literature were incorporated into a database for further analysis. Each measure was categorised using the above five themes, supplemented with a sixth theme which was not used in the categorisation of study focus:

6. **Quantity** – measures of the bio-physical quantity of green space, such as the number of trees, and percentage tree canopy.

There is no implied hierarch or functional relationship within these focal themes.

2.4 Case Studies

Five global case studies were selected from the literature for further study, exploring in greater depth how

[1] Cultural ecosystem services have not been included in this definition. They have been incorporated into other themes in this review.

UGS tools have been used in other global contexts. The neighbourhood, city and regional examples (**Tel Aviv** (Israel), **Delhi** (India), **Beijing** (China), **Stoke-on-Trent** (UK) and **Saxony** (Germany)) were selected based on their demonstration of success and best practice as well as their relevance to the Australian context.

Additionally the MUGS project developed an Australian worked example. This Australian case study used a satellite-based 'greenness' measure known as the Enhanced Vegetation Index (EVI). This UGS measure combines measures of chlorophyll activity (red spectral image) with a near-infrared image to generate a quantitative measure of greenness that can be used to map UGS. The EVI equation was applied to the European Space Agency's Sentinel-2 satellite (at 10m grid cells) to undertake a rapid assessment of UGS in Australian cities.

2.5 Blueprint Development

The blueprint was developed from a synthesis of findings from stakeholder engagement and the literature review (Noblit & Hare, 1988). The blueprint was designed with an informed and technically trained audience in mind, and with a view to drive further demand for an implemented decision-support framework for UGS planning and management. As such, it is both a technical summary of findings from the project and an outlook.

Phase I of the research demonstrated the current state of play in Australia, and also desired next steps in the field; while Phase II demonstrated best practice as per reported by global practitioners. The blueprint brings both of these elements together in a decision-support framework for best practice UGS planning and management in Australia.

Following synthesis, several ideas for visual representation were trialled within the project team. Once a 'storyboard' design had been settled on, a hand-drawn sketch was developed. This sketch was then further discussed with our Project Advisory Group (see Section 2.6 Project Advisory Group below) and subsequently with a communications expert and a professional graphic designer. From there a professional design was developed. The final blueprint is attached in Appendix J.

2.6 Project Advisory Group

A Project Advisory Group (PAG) was established for the project in order to obtain feedback from industry experts and potential end users of a future decision-support framework. Members of the PAG are detailed in Table 1 below.

Table 1 Project Advisory Group Members

	Name	Position	Organisation	Location
1	Sharyn Casey Brenda Kranz	Relationship Manager R&D Manager Green Cities	Hort Innovation	NSW
2	Meg Caffin	Principal	Urban Forest Consulting	VIC
3	Adam Beck	Director + Chief Collaboration Officer	Centre for Urban Innovation	QLD
4	Lucy Sharman	Sustainability Education Manager, Eco-concierge	Barangaroo South (Lend Lease)	NSW
5	John Bunker	Managing Director	Greenlife Solutions	QLD
6	Emil Montibeler	National Business Development Manager	Ozbreed Pty Ltd	NSW

The Project Advisory Group provided feedback on key findings from the research in two teleconference meetings at the following stages of research:

- Towards the finalisation of Phase I, when the majority of stakeholder feedback had been completed and a Discussion Paper developed;
- Towards the finalisation of Phase III, when a draft of the 'blueprint' had been developed.

Minutes were recorded and circulated to the PAG following each meeting.

3. Outputs

This section provides the findings of each of the following research outputs:

- Phase I - Stakeholder Engagement;
    - Part 1 – Interviews
    - Part 2 – Focus Groups
- Phase II – Review;
    - Literature review;
    - Annotated bibliography;
    - Five global case studies;
    - National worked example of a rapid assessment of green space;
- Tools identified from Phase I and Phase II
- Phase III - Blueprint.

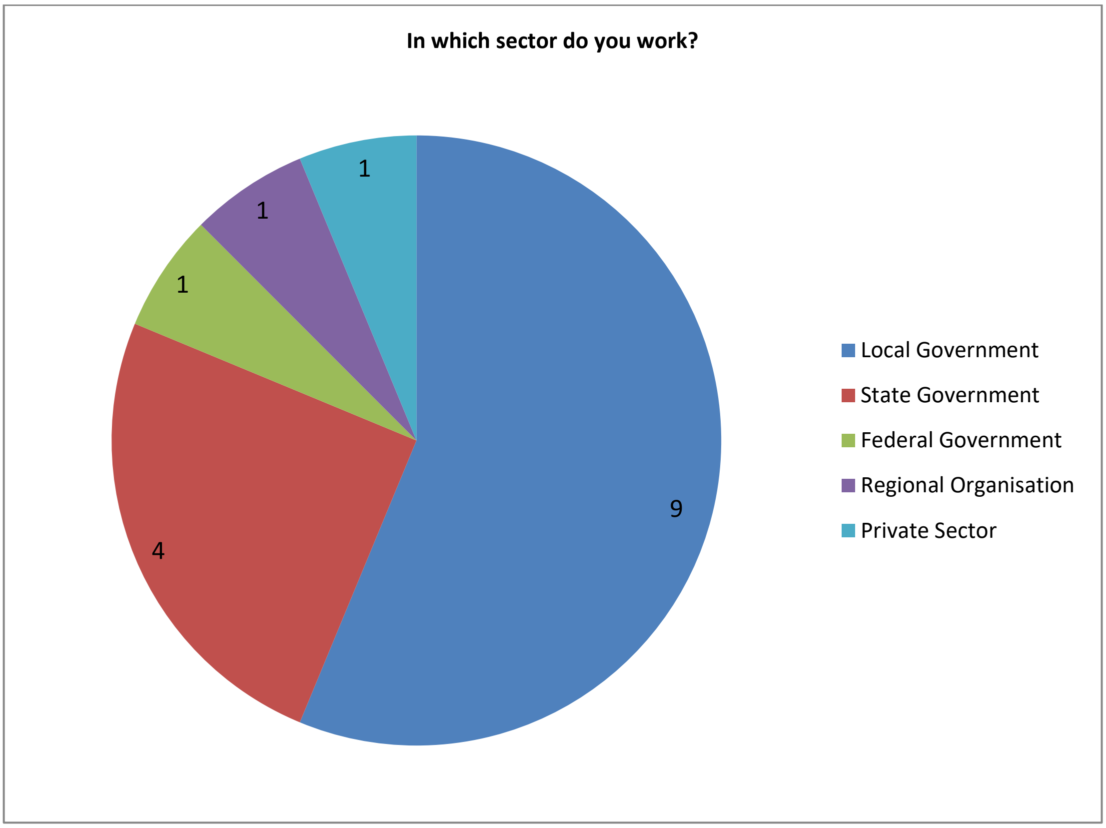
3.1 Phase I - Stakeholder Engagement

3.1.1 Part I - Interviews

Interviewees

As illustrated in Figure 2, over half of the interviewees were from the local government sector, expected to be the key audience for a nationally consistent Australian UGS decision-support framework.

Figure 2*: *Interviewee sector



Interviewees were asked upfront questions about their experience working in the sector generally, and with UGS specifically.

Figure 3 and Figure 4 show that the majority of interviewees had been in their sector for more than 10 years and experience with UGS planning and management was spread between a low –medium and high level of experience.

Figure 3: Interviewee experience in sector

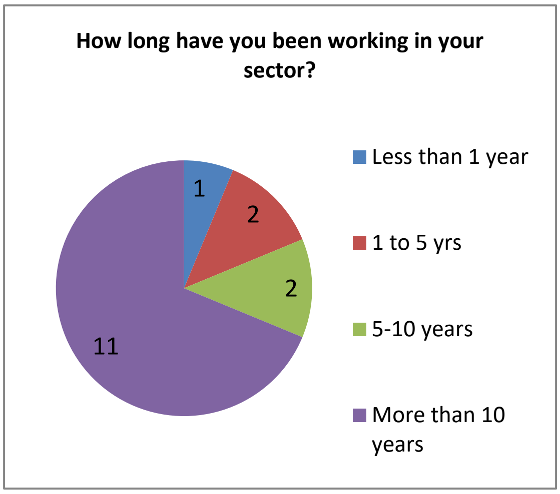
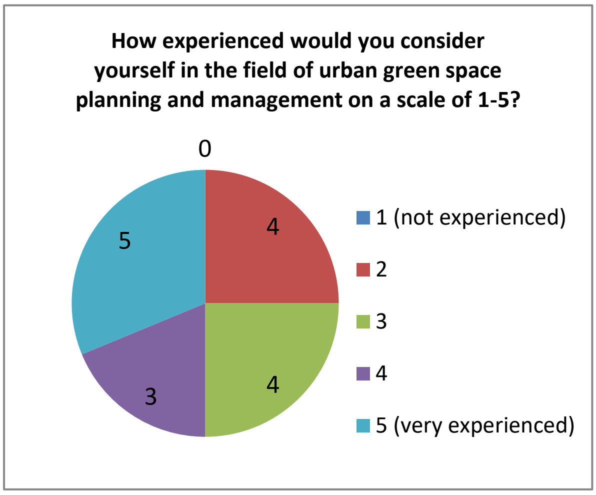


Figure 4: Interviewee experience



Key observations from the interview process:

- Some stakeholders were not working directly with UGS measurement so acted more as 'referral interviewees' that opened up channels to find other interviewees;
- Stakeholders came from a wide range of backgrounds and positions – from policy/management to operations/technical so a wide range of perspectives was represented;
- Some interviewees spoke to a number of policies, programs and projects broadly, others spoke very specifically to one program or initiative - so the information on UGS measures gathered was from macro to micro;
- The questions led to discussions that went in different directions - to broader UGS planning and decision making to very specific details on the ins and outs of a tree planting program;
- When using the term "urban green space" this was often interpreted to mean different things - there were a few discussions about the definition - but once the assumed meaning was given by the interviewee, their definition became the focus of the interview and the examples or experiences they gave (i.e. the interview focused on public open space as they define it rather than any other definition of UGS).

UGS Measures

Range of measures

Interviewees were asked what metrics they were currently using to measure green space. A range of methods were used by stakeholders, ranging from simple GIS-based calculations of UGS area (m^2) to more advanced methods involving remote sensing techniques such as Light Detection and Ranging (LIDAR).

The majority of interviewees confirmed that it was important to clearly define the term “urban” and the term “green space” before deciding on metrics. We did not provide a specific UGS definition to interviewees, but rather asked what definitions or terminology they use. Table 2 below shows the diversity of terminology and definitions for UGS used by interviewees.

Table 2: Definitions and Terminology for UGS

Terminology	Definition or comment
Urban	*"The absolute essence of urbanity is walkability i.e. less than 400m, closer to 150m"*
Urban green space	*"Local government defines urban green space often as traditional park land or mowed lawns"* *"Is it like a golf course, a private golf course? It still looks nice, and you've got that aesthetic value, but you can't actually use it"* *"Is green space places and spaces, is it just parks and conservation reserves, or it streetscapes and is it everything?"*
Urban forests	*"Surfaces that are vegetated, reflective or permeable (i.e. surfaces that mitigate urban heat and therefore will adapt us for future climate change heat. Includes green roofs, green walls, green facades, canopy trees, verge planting, bioswales and water sensitive urban design interventions"* *"Something that is giving a cooling effect"*
Public Open Space	*"E.g. fields or ovals"* *"Urban heat island should not include public open space but should include green space for community"* *"Includes schools"* *"Green space big enough to go and kick a football on and open to the public - it is easier to map whereas private land, you can still gain the benefit of green space, but you can't go out and kick a football on it"* *"What (about) rural per-urban areas...when does bush land or fields and paddocks...become open space?"*
Green Open Space	*"Could be bushland - it is open space that the public can use and have access to"*
Metropolitan Green Space	*"Parks or lawn of a certain square meterage"*
Urban Mosaic	*"..recognising that every place has different limitations and different potential, including recreation…urban green…..different forms of recreation or activity than you might normally associate with open space. That leads to re-conceptualization of the public domain, e.g. streets which are…the major part of the public domain, as having a recreational potential"*
Street trees	
Urban green cover	
Tree Canopy	

Several interviewees mentioned the presence of targets for UGS, whether setting targets or striving to measure progress towards targets. Some mentioned progress towards targets was positive and others negative – this was often dependent on the metrics and method used for measurement. The earliest date a stakeholder had begun measuring green space (vegetation cover specifically) was 1998. Often the targets were set at a state government level and integrated into climate adaptation plans and policies, strategic plans, strategic community plans, infrastructure strategies or corporate plans.

Some examples of targets mentioned by interviewees include:

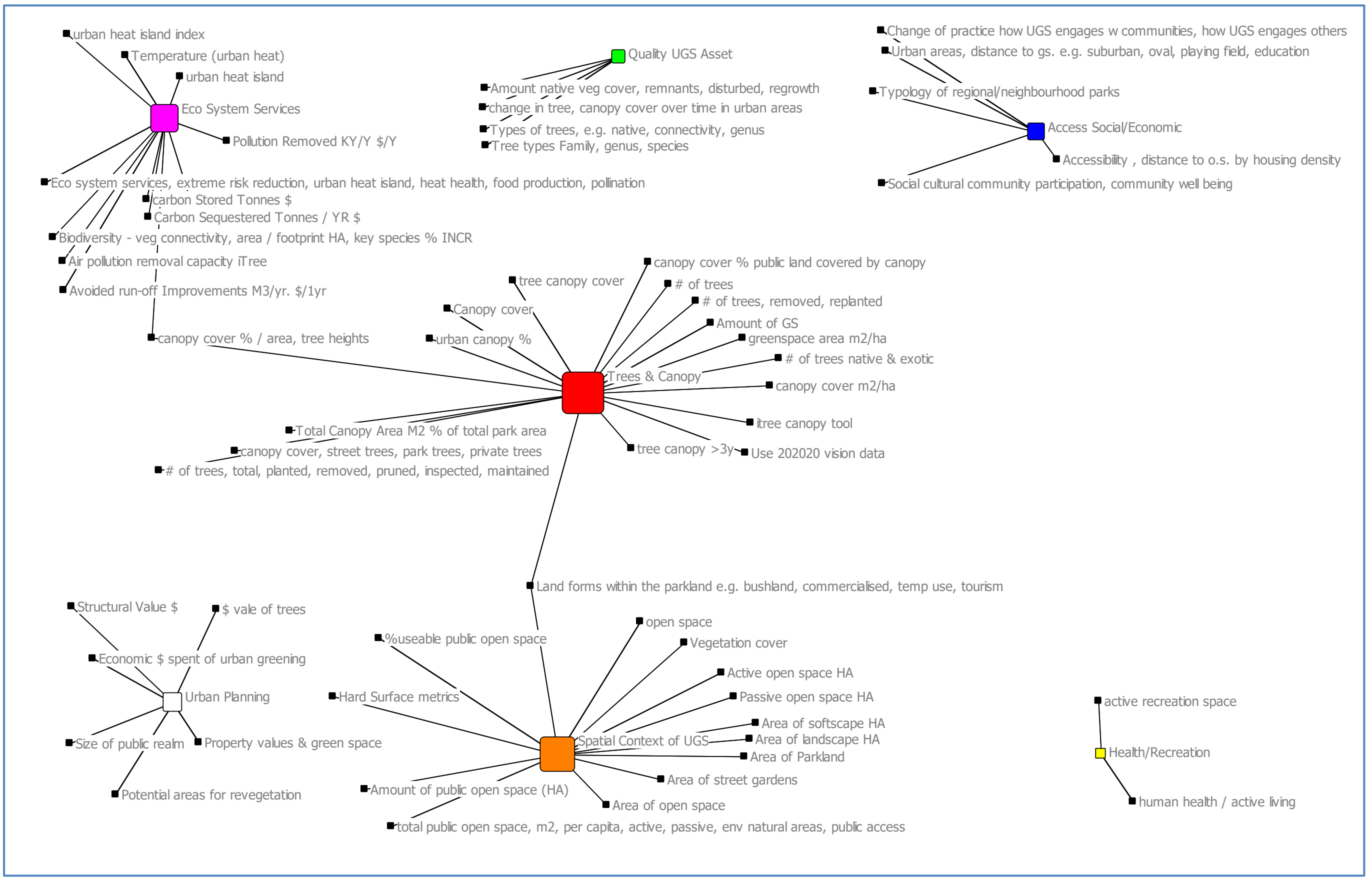
- Increasing canopy cover by 15% by 2030;
- If local government area has <30% tree canopy cover, increase by 20% by 2045;
- No net canopy loss;
- 10% green space in development;

- 10% useable public open space in development;
- 3.36 hectares public open space per 1000 population (15yrold target);

UGS Measures were mapped against literature review preliminary themes of Ecosystem services, Quality, Urban planning, Access / Socio economic, Health and Recreation, Trees & Canopy and Spatial Context.

The resulting qualitative map informed the process of the focus groups in Figure 5: Interview Metrics mapped to Literature review themes. The figure layout refers only to the qualitative mapping by experts. After connection to theme, placement of nodes and length of line are arbitrary.

Figure 5: Interview Metrics mapped to Literature review themes



Positive and Negative Outcomes

Interviewees identified the following ***positive*** outcomes in their experience of measuring UGS

- Engaging stakeholders
    - Using data (environmental, health, heat mapping, "stretch metrics for urban greening") engaged and educated the community, elected members (built case for urban forest), CEO and senior management;
    - Mapping graphics really useful in changing mindsets (e.g. on water conservation);
    - Modelling helped build awareness, build alliances and coordinate responses;
    - Visuals to show serious heat impacts were successful where no visuals were not;
    - Setting targets allowed for a close look actual costs to green a city and educating;

- Policy development
    - Linking adaptation plans to public health plans was a positive exercise;
    - Measured canopy cover prompted development of Urban Forest Strategy.
- Benchmarking and target setting
    - iTree was *“easy to compare local government authorities (LGA), simple to use, free and easier than LIDAR”;*
    - Measuring canopy cover *"allowed understanding of city and benchmarking against other cities internationally";*
    - Benchmarking against like-agencies generates and promotes innovation;
    - Measuring tree canopy found increase and allowed suburb comparisons, gave target to work towards.
- Environmental benefits
    - Planted 6,000 trees in last 2 years;
    - Dollar value on trees (asset value + ecosystem service value) helps to retain them.
- Recognition
    - Won NSW award for biodiversity.
- Other
    - 202020 Vision comparison of different models Councils can use was helpful;
    - Researched and published paper on vegetation cover and urban heat which:
        - gave clear relationship between protected cover and heat mitigation;
        - was incorporated into technical guidelines;
        - formed evidence base of a program approach benefits of urban green cover.
    - Maximising data *then* defining goals was a positive approach;
    - User surveys gave evidence of disincentives, informed design for positive outcomes.

Interviewees identified the following ***negative*** outcomes in their experience of measuring UGS.

- Funding, time or resource limitations
    - Projects or funding being discontinued;
    - Multiple stakeholders involved in measuring takes longer;
    - *“Obtaining data is expensive, analysis is cheap”;*
- Staff, data or technology capabilities
    - Needed to change methodology based on staff capabilities;
    - Mapping/modelling green spaces without advanced skills = "blind" decision making;
    - *"Technology moves so quickly, unless you're in this space you can't keep up with it";*
    - Urban heat measurement complicated/expensive to acquire and to rectify product;
    - No demand to justify a high quality industry to provide UGS data;

    - *“Some Councils have GIS capability, some don't. Some good records, some not”;*
- Measuring over time/evolving methods or data
    - Metrics may not necessarily measure directly against targets that were originally set;
    - Metrics reflecting time lag between new development, renewal or parklands;
    - Changing method (to increase accuracy) resulted in decrease (to increase) in canopy;
    - Measuring all open space showed different result to just liveable open space in LGA;
    - Not useful to use historical data - need to use projections data;
    - Socioeconomic indicators as stand-alone indicator not successful;
    - “Tool didn't include thermal measures”.
    - *“Standards-based and formulaic approaches to urban planning lead to un-walkable results”;*
    - Important to temper comparisons between cities with their context;
    - Data differs between states - difficult to develop one comprehensive GIS data set;
    - *"No good just measuring number of trees…need to look at all elements involved”.*
- Acceptance
    - *“Everybody loves trees but nobody wants them”;*
    - Convincing community & City of social/ecosystem service benefits of green space;
    - *"There is convincing we have to do on a daily basis..metrics..would be beneficial";*
    - Tension between achieving infill targets and preserving trees;
    - Tension between preserving trees and suburban development (clear felling);
    - Challenge with privately owned land and managing green space.

Gaps in Measures

Interviewees were asked “Have you experienced any particular gaps in UGS metrics?” The majority of interviewees agreed that gaps in UGS metrics are prevalent and that work is required to ensure a comprehensive set of useful and practical UGS measures are available.

Several interviewees identified more detailed data on trees (e.g. vegetation health, loss rate, volumetric measures, species) was necessary. A common theme was the need for metrics that measure the quality and value of open space, for example the value of green space to the community; real estate value of tree-lined vs non-tree-lined streets; and the value of investing in green space upgrades. Additional gaps identified by interviewees included measures of the urban heat island effect; measures of the social health & wellbeing benefits from green space (e.g. rates of obesity or other diseases); measures of the value of *private* open space and the biodiversity and conservation value of green space such as mix of species, benefit of understory to native fauna. One interviewee suggested ‘triple bottom line’ indicators that combine land value with amenity and health benefits would be helpful.

Interviewees also identified gaps in the methods for measuring UGS (e.g. spatial mapping to measure canopy cover) and suggested that tools such as iTree be more widely used. The need for a consistent data set (e.g. a national green space data layer) was identified as another gap, as each state currently uses different classifications (and numbers of classifications) for UGS. Access to a range of data and metrics was also highlighted as lacking.

Do's and Don'ts

Table 3 below provides a summary of interview responses when Interviewees were asked about their suggested "do's" and "don't's" for measuring UGS.

Table 3: Do's and Don't's for measuring UGS

Do's	Don'ts
• Clearly define what is included in the measure and what is not • Have a system to review and assess metrics • Define why you are measuring • Define who is measuring • Clearly define the function of UGS e.g. biodiversity or ecological value, heat mitigation, storm water etc. • Use fine scale that redeems and maintains vigour • Use metrics that are easily visualised • Talk to stakeholders who will use mapping (what systems they use, how they like to receive data or mapping and whether it needs to be in certain format/scale to be integrated into reporting, monitoring or decision making) • Do not measure "because it has to be done", but measure "so it can be used to inform decision making" • Think laterally • Consider counter to metrics: urban design-led, social place-based, contextual response • Make layers removable e.g. start with all green space, then remove for example types of vegetation (a user-defined definition of green space)	• Do not be bound to standards that have been derived from previous practices • Do not vaguely define metric • Be aware of legacy issues (e.g. appropriate tree species) • Do not measure urban forestry using number of trees - instead use canopy coverage to see big picture • Do not lose sight of "the democratisation of space" by using pure metrics

Characteristics of UGS decision-support framework

Interviewees were then asked a series of questions about the approaches, format and application of a potential decision-support framework for measuring UGS.

As illustrated in Figure 6 over half of the respondents identified that ***an online tool*** would be preferable for their use compared to stand-alone software. Some respondents mentioned that a GIS application could be provided online, but also be downloadable. By far, the majority of respondents would prefer ***a shared tool*** than one that is used in-house and not shared, as illustrated in Figure 7. Figure 8 shows a clear preference for a tool that provides quantitative data.

Figure 6: Preference for tool format

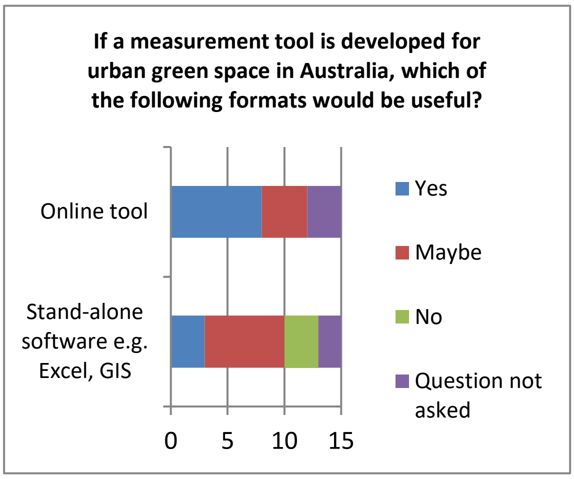


Figure 7: Preference for uses of a tool

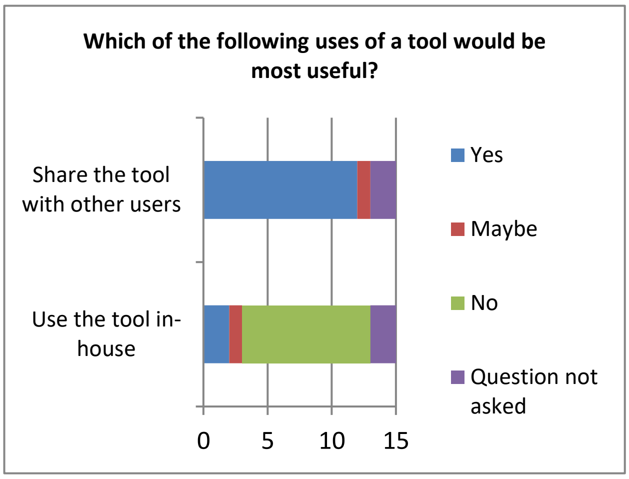
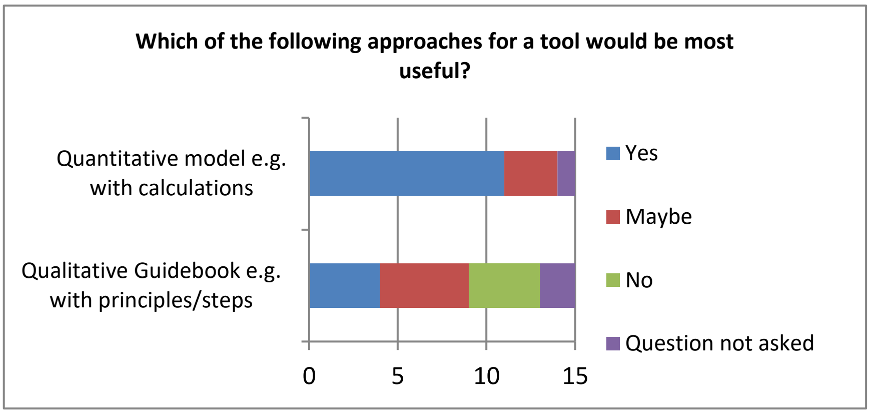


Figure 8: Preference for approach to tool



Some feedback from interviewees included:

- MS Excel out of date, all GIS datasets now going online;
- Web-based tools simplest, can be used by multiple audiences, GIS is specific for users;
- Mapping software providers change/discontinue products which can be a problem;
- Council IT policies are important to consider, security a concern;
- Make layers downloadable to interact with Council special layers;
- Public to visualise data and compare LGAs without GIS skills/software would be useful;
- Export data to a CD or shape file to import into in-house software;
- Online tool with an input database that would continually update;
- Would be helpful to transfer data onto an actual tablet for field workers;
- Complexity is important;
- Having data already processed is useful;
- Real time calculator with metrics and calculations on values or benefit to wider community;
- Specifications/ qualitative guidance as configuration steps to build purpose-specific product;
- Green space data useful for whole country- a guide book/specification would be handy;
- *"20/20/20 Vision has been doing in terms of your 'ABCs' of building an urban forest or talking to traffic engineers is pretty useful";*
- Allow comparisons between councils, states and nationally;
- Inputs data and get result - not think too much about what's happening behind the scenes;
- Provide clear "how to" guidance;

- Simple and quick is best - plug in data and hit "go";
- *"If you're looking at business cases, then you need numbers";*
- *"I don't think you're ever going to have a definitive 'this is the way to do it' "*
- *"If measuring tree canopy – quantitative, if measuring veg health - qualitative"*
- Offer qualitative content upfront but metrics have "the grunt and that's what we need";
- Community should be able to access data - can encourage local government to measure;
- Precinct/property developers could access data - assist in regional planning;
- Shared, secure tool would streamline data collection and help compare apples with apples
- Shared data would be ideal, but anonymised;
- *"We need to share and we need to share more often….we need to work as a collective";*
- Show baselines/comparative figures from other cities to community/elected members;
- *"I think all data now is going open source";*
- Allow for all different users to access;
- *"If interest on the part of academia or private sector, vet government down solidly";*
- Will be challenging to get state governments to agree to a national tool;
- Tool should have real rigour and science behind the engine but people input information to build a database e.g. Wikipedia.

3.1.2 Part 2 – Focus Groups

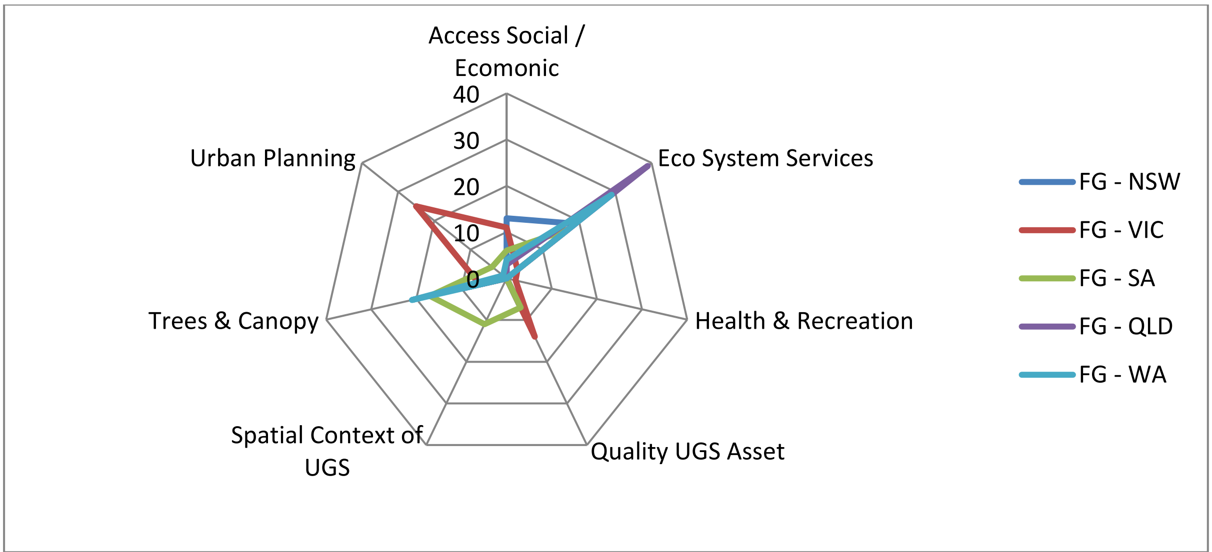
Activity 1: What UGS Measures

Within this element of the Focus Groups, participants were asked to individually list the measures used and desired. These individual nominations were then grouped into themes using affinity mapping. Affinity mapping is a simplified version of the KJ method (Scupin, 1997). The process took place as per the methodology outlined in Section 2.2 Focus Groups. The affinity maps are contained in Appendix E.

As illustrated in Figure 9 , once the affinity maps were compiled, the groupings provided by participants were then thematically mapped by researchers onto the themes outlined from the literature review (as described in Section 2.3 Literature Review).

In the majority of the Focus Groups both the Trees & Canopy and the Quality and Assessment of the Assets and Urban Planning themes have the majority of measures. Measures around biodiversity and performance of UGS remain under-represented; however these are mentioned within the desired "wish list" metrics.

Figure 9: Thematic groupings of UGS measures from all five Focus Groups mapped onto Themes found in literature. The scale (0-40) represents counts of measures within each thematic group, e.g. the Ecosystem Services thematic group received 39 nominated measures in the QLD Focus Group.



In order to arrive at a synthesis of thematic groupings of UGS measures, we mapped the thematic grouping found in each Focus Group onto the themes initially found in literature[2]. The results (Figure 9) show that whilst the nominated themes themselves corresponded strongly with those found in literature, the degree to which the nominated measures match the scientific state of the art is consistent (with exception of the Ecosystem Services theme).

Activity 2: Use situations

The second main activity undertaken in the Focus Groups focussed on the application of UGS measures (current and potential), with a view to identify use situations (decisions on UGS that participants are facing in their day to day work). Based on insights from the first activity ("What UGS measures?") and participants' professional experience, they were asked to identify a use situation and develop a worked example of the application of new or additional UGS metrics. These could be based on, for example: spatial scales; policy

[2] The grouping presented in this Figure was undertaken in parallel with the early stages of the literature review. At that stage, seven themes had been identified. These seven themes were subsequently consolidated in the six themes (per Section 2.3) that were used to discuss the literature in the current report.

domains; or time scales of decision-making (one-off planning decisions vs ongoing management) or monitoring and evaluation. After a use situation had been identified and agreed upon, participants were asked to describe the situation and discuss metrics, using post-it notes and butcher's paper. Table 4 outlines the use situations discussed by each Focus Group. The detailed summary is available in Appendix F.

Table 4: Location and use situations from all five Focus Groups

Location	Use situation 1	Use situation 2
NSW	Loss of open [green] space to other land uses – liveability of urban areas	Adapting to climate change
VIC	Contested [green] infrastructure for green space	Multifunctional use of open space, especially sports clubs
SA	Urban Infill – Private vs Public Space	Community Health and UGS
WA	Metrics that explore urban green spaces with joint ownership	Ecosystem Services vs Risk
QLD	Municipality tree planting	Changing the message around asset management

Activity 3: Characteristics of a nationally consistent approach for measuring UGS

Within this exercise, participants discussed a potential nationally consistent approach (referred to simply as 'tool' in the Focus Groups, as was used in the interviews) for measuring Australian UGS. If there was such an approach, what would they want it to be? To this end a voting exercise was undertaken, inviting participants to respond to questions regarding custodianship, data sharing policy and skill level results. Responses are outlined in Figure 10 -11below (y axis denotes number of participant nominations). Participants were divided as to who should be the custodian of the tool; almost all participants agreed that the data should be shared with the exception of three participants in regards to data sharing at scale, for example sharing data at a city rather than national level. The majority of participants responded that there is currently a policy gap regarding UGS, and the expected user of said tool would be a trained, competent and intermediate user.

Figure 10: Tool Custodianship

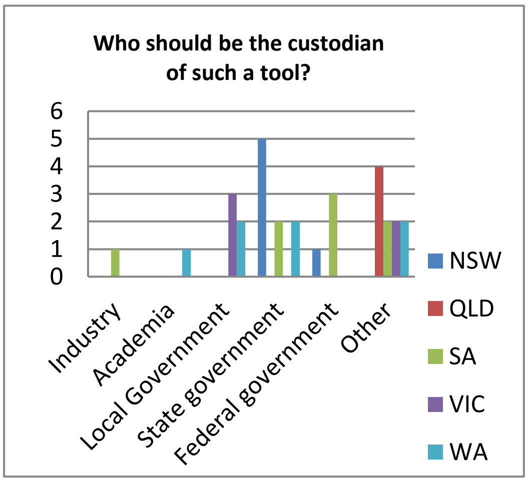


Figure 11: Data sharing

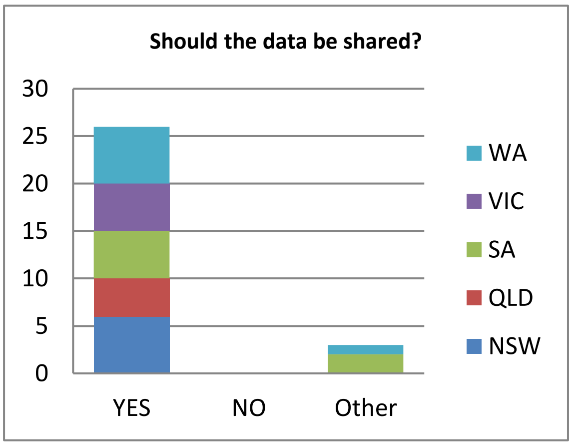
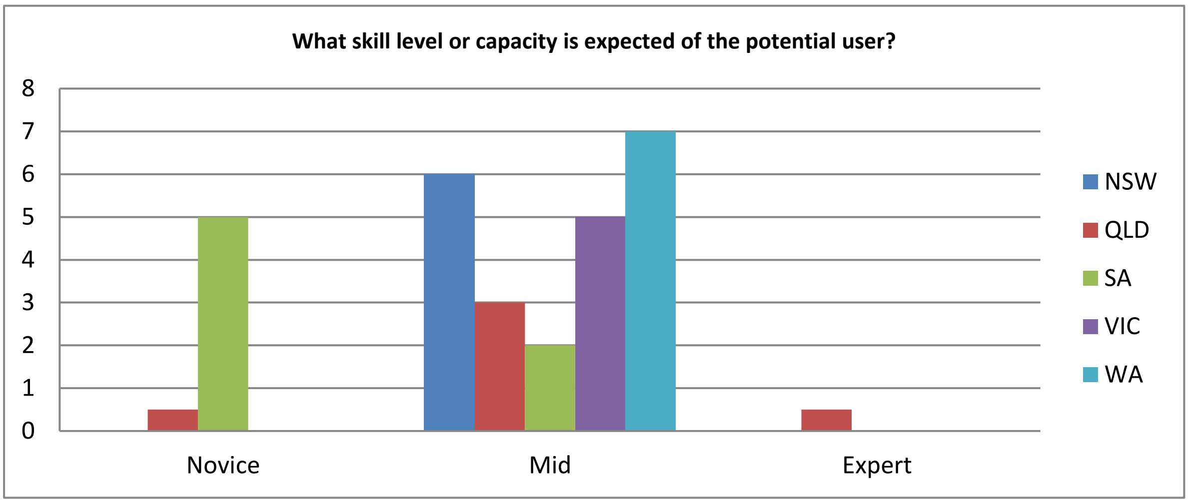


Figure 12: Skill expectation of user



In summary, Focus Group participants reported that the majority of measures currently used exist within the 'Ecosystem Services', 'Urban Planning', 'Trees & Canopy' and 'Quality of UGS Asset' themes. This may be due to the fact that many of these measures are more readily quantifiable and have historically been used in various municipalities nationally (e.g., percentage of tree canopy; distance from dwellings to green spaces, etc.). From the discussion of use situations it became apparent that there is a need to couple disparate data sets (such as measures pertaining to health and recreation, access and social and economic benefits). Focus Group participants, in their capacity as potential users of a nationally consistent approach, also asked more complex questions regarding UGS (e.g. how can childhood obesity rates be positively affected by the implementation of safe, shady, and connected footpaths/bicycle paths to schools and other amenities?).

3.1.3 Tools identified within interviews and focus groups

Within the interviews and focus groups participants mentioned a diverse range of "tools" (methods, approaches, frameworks, software) that they used, were familiar with, or were aware of. Interviewees and participants spoke of ways they measure UGS. Table 5 outlines the tools participants reported using. The criteria used for the classification are explained further in Section 3.2.

Table 5: Overview of tools from Phase I

Name of tool (hard/soft)	Focus	Application	Scale	Limitations
iTree **(hard)**	Bio-physical measurement	Estimating proportion land-use category (e.g., vegetated areas)	Up to neighbourhood scale	Heavily resource intensive. Questionable robustness.
CSIRO Urban Monitor (hard)	Bio-physical measurement	Four-band aerial photography monitoring system, broad scale vegetation mapping (layers of grass, trees and shrubs)	Regional	Distribution limited as very large files. Nationally developed tool but has been applied specifically in WA.
Hort Innovation Green to Gold tool (TBA)	Platform aggregates data sets and predictive analytics on "financial, social and health dividends of trees and plants over time"	TBC – under development	TBC – under development ("local and state governments")	TBC – under development
Department of t Planning WA - Liveable Neighbourhoods(soft)	Policy for liveable neighbourhoods, ensuring developments have green spaces	Policy document only	Neighbourhood and municipality	As a set of guidelines it is limited as to how these are promoted and enforced.
Centre for Low Carbon Living urban green cover guidelines & urban heat project **(soft)**	Policy and guideline document for green cover	In conjunction with recent NSW climate change policy metrics provide robust pathway		Mentioned as Centre for Low Carbon Living – actual guidelines **NSW Office of Environment and Heritage - Urban Green Cover Technical Guidelines**

Name of tool (hard/soft)	Focus	Application	Scale	Limitations
Urban Ecology Renewal Initiative Macquarie University **(soft)**	Guideline document	Developing evidence for embedding urban ecology into urban development policy	Urban	As a set of guidelines it is limited as to how these are promoted and enforced
Integrated Open Space Services **(hard)**	Benchmarking of parks around Australia	Proprietary software performed by consultants.	National, state by state, municipality	Often reliant on intercept surveys – exploring opinions of participation of green spaces, rather than interacting with those not using urban green spaces
ACTMAPi - ACT Land Use database **(hard)**	ACT land use Bio-physical measurement	ACT land use - Explores land use and custodianship, developments, roads, heritage sites and licenses	Fine grained to individual property	Overlays do not include liveability, health data etc.
Victorian Land Use Information System (V-LUIS) (hard)	Bio-physical measurement	VIC land use - Spatial dataset on land tenure, land use and land cover for each cadastral parcel in the state of Victoria	Fine grained to cadastral parcels	'Strategic product' so for a broad range of uses
ArbourTrack (hard)	Bio-physical measurement	Geographic information system based tree management software solution. Software links to standard or differential GPS for accurate tree placement.	To manage individual, stands or groupings of trees.	Private company (ArbourTrack Pty Ltd and Trinova Systems Ltd)

Other policies, processes or guidelines for measuring UGS interviewees identified using or being familiar with included:

- Water Sensitive Cities Index – the Index is "a tool that offers users the ability to benchmark cities (at the metropolitan or municipal scale), based on performance against a range of urban water indicators that characterise a water sensitive city". This was suggested as a tool by one interviewee with a useful format that could be adapted for urban green spaces i.e. a similar index could be developed for urban green spaces
- WA Liveable Neighbourhoods policy (Department of Planning) – this is a state "operational policy that guides the structure planning and subdivision for greenfield and large brownfield (urban infill) sites", while not a tool, it was raised by an interviewee as a useful policy mechanism for guiding UGS measurement
- NSW Urban Green Cover Guidelines (Centre for Low Carbon Living) – these are state government guidelines for "built environment professionals working in state and local government and the private sector practical information and typical details to encourage best practice applications of green cover, so as to minimise urban heat impacts across NSW" while not a tool, it was raised by an interviewee as useful guidance for UGS measurement
- Urban Ecology Renewal Investigation Project is a research project (commenced in 2016) to gain an improved knowledge and understanding of the gaps and opportunities that exist to improve urban ecology outcomes in the Greater Sydney Region – this was suggested as a resource by an interviewee
- Park User Satisfaction Survey (Integrated Open Space Services/IOSS) – this survey (delivered by private research company IOSS) was highlighted as a useful benchmarking tool for comparing parks and open spaces, this is believed to be part of the wider ParksBase web based program IOSS and Parks and Leisure Australia (PLA), which "collects, organises and reports on information about public open space planning and management".

There were also a number of programs and initiatives identified by interviewees that are relevant to UGS planning and measurement. These include:

- Urban Tree Canopy Project WA Dept Planning (uses CSIRO Urban Monitoring Tool – 2009 released, currently updating to 2014 with CSIRO)
- WA Bush Forever program
- Commonwealth Smart Cities Plan
- Gold Coast public open space measures:
  - Parks facilities
  - Vegetation cover, vegetation types and the vegetation community metrics used to categorise and protect vegetation within the Gold Coast's City Plan
- NSW Metro Greenspace Program
- Melbourne Metropolitan Urban Forest Strategy for Resilient Melbourne
- Greening the West strategy
- CSIRO Urban Living Lab research hub in Sydney
- Clean Air and Urban Landscapes Hub (CAUL Hub)

Additional tools or mechanisms identified in the media during the course of the project include:

- Treepedia: Calculating the Value of Urban Tree Canopy - project by the MIT Senseable City Lab measuring the green canopy of cities using Google Street View panoramas to calculate a Green View Index of 17 world cities to date (including Sydney)

3.2 Phase II - Review

3.2.1 Literature Review

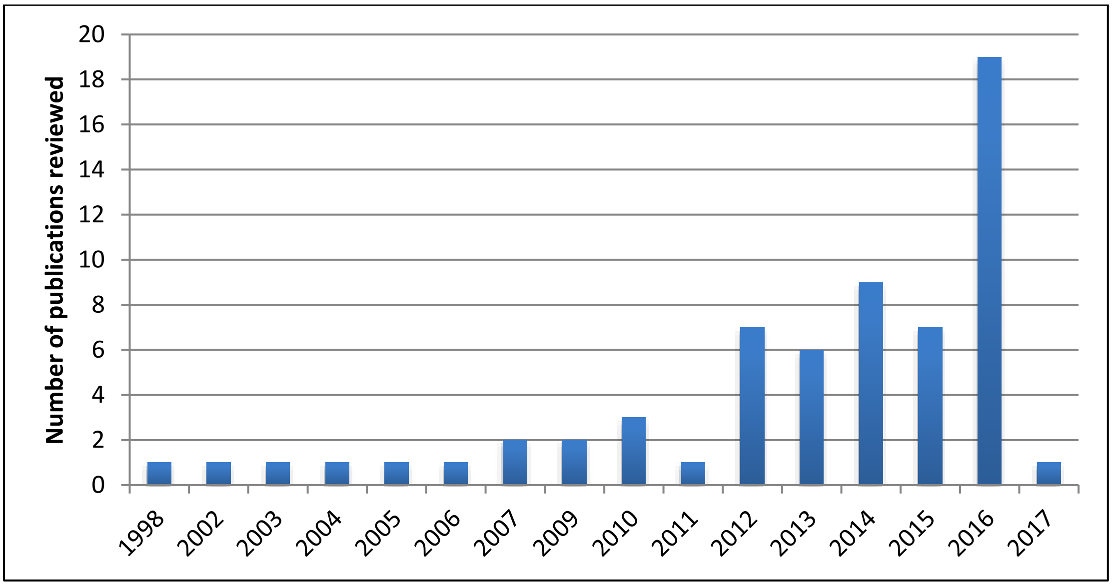
This section presents findings from a broad review of academic literature on current approaches, theory and methods regarding the measurement of UGS. Factors considered in the review include **definitions** of UGS (e.g., urban vegetation; public open green space, etc.), relevant **indicators** and whether they can be readily quantified (e.g., vegetation coverage; green space quality; ecosystem services provision, etc.), and **scale** of analysis (e.g., city vs. neighbourhood vs. region vs. country).

The following sections outline the key findings from the literature undertaken as per the method outlined in Section 2.3 Literature Review.

Overview of literature sources

Literature collected spanned two decades of academic research, with the earliest literature reviewed published in 1998, and most recently in 2017. The bulk of the research reviewed was published in the period 2012 to 2016. Figure 13 below shows the number of papers that were reviewed and their dates of publication.

Figure 13: Number of publications reviewed by year

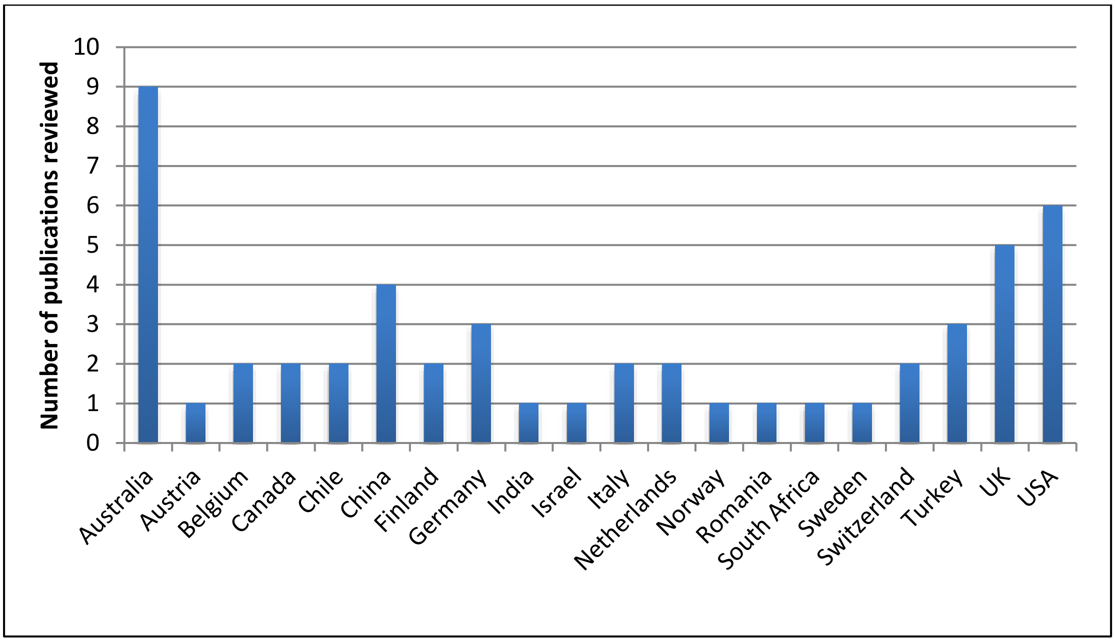


Reviewed literature was published across 37 academic outlets, with the majority of papers coming from the following journals:

- Ecological Indicators
- Landscape and Urban Planning
- Urban Forestry & Urban Greening
- Ecological Economics

The countries of affiliation of corresponding authors were also examined (Figure 14). This serves as a proxy for where the research has taken place, but not necessarily where the area under investigation was located. This assumes that the corresponding author is the primary investigator of the research, and that the research was primarily undertaken at the corresponding author's affiliated research centre.

Figure 14: Author country of affiliation



High-level Findings

Measurement of UGS: bio-physical characteristics and performance

There were two relevant overarching themes across the research analysed; that is, the measurement of **bio-physical** UGS, and the measurement of the **performance** of UGS. There is an important distinction between the two, particularly in regards to benchmarking and meeting local government strategic goals and targets.

Measuring the bio-physical characteristics of green space is particularly important when benchmarking the green space character of an area under investigation. Bio-physical characteristics measured include the number of trees, tree canopy, number of parks, size of green space, etc. These characteristics provide relatively straightforward metrics for benchmarking (for example, trees in year *t*) and for goal setting (for example, increase in the number of trees in year *t*). Moreover, collecting data to determine these indicators is relatively straightforward, with varying degrees of expertise required depending on the characteristics being measured and the methods used. A key example is in measuring the number of trees through sampling over a small area, and using remote sensing to estimate the number of trees over a large area through image segmentation.

Measuring bio-physical green space is advantageous as it provides a meaningful raw indicator of green space, and can be used to inform further metrics. Interestingly, very few papers reviewed in the academic literature focused entirely on bio-physical measures, and many acknowledged the importance of using holistic indicators to measure green space performance. However, nearly all papers reviewed used bio-physical indicators as part of composite indicators, or as part of a more holistic measurement of general green space performance (for example, number of trees, parks within walking distance to residential areas, and percentage canopy coverage). Locational measures are also good examples of composite' measures, e.g. an overlay of a school location map with a green space map, resulting in a map showing "distance to and association with green space".

A performance perspective on green space measurement requires defining what performance is. For example, performance-based measures could be defined as measures of UGS *in-context*. For example, green space could be measured with consideration to biodiversity potential, ecosystem provision, recreation benefits, etc. Measuring green space in this way provides a holistic measure of green space. Performance-based measures can be more complex to calculate and typically require bio-physical measures.

Oftentimes both bio-physical and performance-based measures are necessary: one cannot begin to look at performance without the bio-physical measure and the bio-physical measures only gain meaning when coupled to performance.

UGS indicators

From the analysis conducted, we can derive the following definitions for indicators and metrics that are essential for further discussion:

- **Sub-indicator (or sub-metric)** – some form of measure or variable of interest (e.g., number of trees, percentage green space coverage, etc.).
- **Indicator (or metric)** – some form of measurement of a category interest (e.g., ecosystem services performance, green space quality, etc.). Indicators are often made up of sub-indicators. For example, an indicator for ecological performance of green space might include sub-indicators for species diversity, ecological risks, number of trees, and canopy coverage.

The above definitions imply a **hierarchy** in that indicators can be made up of one or more sub-indicators. A simple example could be an indicator for green space quality. This measure could be composed of multiple indicators that describe green space quantity in an area under investigation, such as the number of trees, percentage tree canopy cover, and the level of amenity provided.

Several papers use this hierarchy to examine green space, with multiple (or sometimes single) sub-indicators describing some indicator of performance. Indicators themselves sometimes feature in a hierarchy - these are termed **composite-indicators**: several indicators (and sub-indicators) are combined to fully describe the performance of green space in the area under investigation in a single score. For example, indicators for ecosystem service provision, green space quality, etc. (all composed of single or multiple indicators) can be combined into a single composite-indicator that evaluates the performance of green space, with consideration to those indicators included in the composite-metric.

This approach is useful as it can reduce several sub-indicators and indicators into a single score that evaluates green space with consideration to all variables of interest, to varying degrees of complexity. Alam et al. (2016) develop a composite ecological service index, with consideration of the trade-offs between simplicity and complexity by containing two levels of indicators—one level containing simple indicators, the other level containing a greater number of indicators. The trade-off for simplicity is less robustness and accuracy, and conversely the trade-off for complexity is greater data requirements and practitioner knowledge. Alam et al. (2016) present an example of their framework for measuring air quality regulation. A simple composite measure would contain sub-indicators for area of forest, street density and vehicle load, whereas a complex composite would include leaf area index (derived from remote sensing data), weather data, pollutant particle concentration, and other data intensive measures.

A critical requirement of using composite-indicators is the weighting of variables by importance. Such weighting can be done through a participatory approach (e.g. an analytic hierarchy process), following a statistical approach (e.g. principal component analysis), or an approach that assigns equal weighting to all variables (e.g. Blanc et al. 2008 and Nardo et al. 2005 in Alam). Pakzad and Osmond (2016) propose a hierarchical set of indicators for measuring the sustainability performance of urban green infrastructure generally based on a 'driving force-pressure-state-impact-response' ecological modelling framework and stakeholder interviews with Australian experts in urban green infrastructure, classifying interview responses into categories for which draft indicators are chosen. Although this paper is conceptual and not applied, it gives background on indicators that are relevant to the Australian environment.

Actual sub-indicators and indicators used across the literature are broad. These reflect the varied nature, focus and locations of the research conducted. There are too many varied indicators to list in this paper, hence the categorisation of indicators into themes. Table 6 contains a percentage breakdown of all indicators used across the papers. This is a raw percentage, but is important to note that some papers contain multiple indicators within a single category.

Many indicators used in the literature are derived from ecosystem services indicators and measures, and landscape metrics. Indicators for ecosystem services exist to measure the condition of an ecosystem, and the performance of the services the ecosystem provides. Therefore, ecosystem service indicators are particularly relevant given the importance of considering the environmental benefits of UGS, and feature strongly in papers where such benefit is quantified to measure performance. Landscape metrics quantify specific spatial characteristics of land use categories, and are used particularly in analyses where GIS and/or remote sensing tools are utilised. Examples of landscape metrics include indicators such as proportional abundance of a class (for example, percentage tree canopy coverage, percentage park land, etc.), richness (e.g., the number of different vegetation types, or number of different parkland types), and spatial configuration. In the literature reviewed, landscape metrics were particularly relevant in studies focused on accessibility and green space quality. Landscape metrics can be used as a proxy (or indicator) to assess ecosystem service performance itself. Frank et al. (2012) presents a methodology for assessing ecosystem services using landscape metrics with relevance to urban landscape planning. Their research found that incorporating landscape metrics into an assessment of ecosystem services contributes to a more realistic appraisal of the potential for landscapes to provide ecosystem services beyond the contribution of single ecosystem services of land class (for example, vegetation).

Selection of UGS measures

Indicators and metrics are commonly used by planners to assess progress towards strategic goals. However, selection of relevant indicator sets is difficult, and highly dependent on a number of factors including availability of data and resources, and applicability to the area under investigation. In Harshaw et al (2007), the characteristics of a good indicator (set) are:

- Relevant
- Credible
- Measurable
- Cost-effective
- Connected to urban forestry

The selection of indicators is sometimes intuitive, for example bio-physical quantity measures of green space. These indicators represent straightforward measures of UGS, and on occasion are potentially interchangeable, depending on the focus of the application. For example, the number of trees and the percentage green space are highly correlated, therefore potentially interchangeable. For some other applications (e.g., urban landscape planning studies), the bio-physical quantity of trees is a more important indicator than percentage tree canopy, when green asset inventory is important, therefore not interchangeable. Nevertheless, as previously stated bio-physical quantity measures are perhaps considered “core” indicators for measuring performance. The selection of bio-physical measurement indicators is then dependent on the application (and whether indicators such as canopy coverage and number of trees for example is interchangeable for example), and available data/expertise.

Some studies perform a multi-criteria decision-making framework (e.g. analytical hierarchy process, or analytic hierarchy process (AHP) to derive the most meaningful indicators for measuring green space performance. This method is based on stakeholder engagement, and is therefore useful for deriving the key indicators of importance given a particular locality and application.

Certain applications of UGS metrics require certain indicators to measure. For example, ecosystem services performance requires very specific (sub-)indicators to measure, such as carbon sequestration, and biodiversity connectivity. These (sub-)indicators however are often derived from other measures, namely bio-physical quantity measures. UGS quality indicators might include extremely varied indicators, from species richness, to the quality and provision of amenities.

In summary, there is complexity in selecting indicators and it would be challenging to create a completely generic set of indicators for measuring UGS performance across different localities and scales.

Application of UGS measures: methods, scale and outcomes

A high diversity of methods, scales and outcome foci was evident from the review of the literature. This diversity reflects the broad research that is being conducted in this field. The application of metrics is highly dependent on the expected outcomes of the investigation, which determines what metrics/indicators are used, as well as what scale and what methods are employed.

Methods used across the reviewed literature are varied, ranging from highly qualitative research into definitions of green space, to highly quantitative research and remote sensing. Primarily, the reviewed research is somewhat quantitative in nature, with composite-metrics employing some kind of regression analysis, multi-criteria analysis, or other mathematical technique. The measurement of many indicators, including tree counts and canopy coverage, and ecosystem services, requires advanced analytical tools or modelling techniques. The more complex the issue under investigation, the greater the complexities in the methods used. Broad performance-based measures, covering ecosystem services, health and recreation, and accessibility require a greater level of complexity for example when compared to applications where the number of trees is the single metric investigated.

The scale of application of metrics and indicators in the literature is also quite broad, however with primary focus on local rather than regional scales. Applications tend to be on the neighbourhood or city level rather than the regional (county, state, etc.). Scale is also a determinant in the complexity of application - if the scale is large, there is greater variability of potentially influencing factors of green space, for example, socioeconomics. Oftentimes, a greater scale also means more difficult data collection, particularly if in-situ measures are required for an analysis (for example, on the ground CO_2 readings, on the ground tree counts, etc.).

Definitions of UGS

A variety of definitions of "urban green space" is found in the literature; all of which require different measures of performance, methods of quantification, and data collection etc.

Taylor and Hochuli (2017) present a literature review of studies in UGS to demonstrate that current definitions of "urban green space" are rather broad and complex. Moreover, the authors found that **six types of definitions** of green space could be identified:

1. Acknowledged range/levels of greenness;
2. Definition by examples (e.g. where green space is defined explicitly by use);
3. Ecosystem services (where green space is defined by the ecosystem service contribution);
4. Green areas;
5. Land use (e.g. undeveloped land, recreational parks, etc.);
6. Vegetated areas.

Taylor and Hochuli (2017) found that the majority of papers defined green space as **vegetated areas**. This agrees with the literature review performed for this project. However, **land use** is also a key descriptor of UGS in the reviewed literature. Some studies are concerned with **public open space** (POS), which may consist of vegetated areas in addition to recreational areas, highlighting the argument in Taylor et al that defining green space is complex, and heavily dependent on the application. Badiu et al. (2016) review categories of public accessible UGS, and these categories include:

- Parks
- Street trees
- School green areas
- Public institution gardens
- Residential gardens
- Cemeteries
- Sports ground
- Town squares
- Urban forests
- Green spaces of industrial and commercial production

Ultimately, this review has used a broad definition of UGS, including aspects of land use, vegetated areas and ecosystem services. Also common in the literature is reference to **green infrastructure**, which is defined by the European Commission as "…a strategically planned network of high quality natural and semi-natural areas with other environmental features, which is designed and managed to deliver a wide range of ecosystem services and protect biodiversity in both rural and urban settings" (European Commission, 2013). As such the definition of urban green infrastructure is within scope as it refers to UGS. However, often in the literature UGS also includes aspects of the built environment (green roofs, vertical gardens, green houses etc.). These aspects are specifically excluded from the above definition of green infrastructure.

UGS Measures in Use

There exists a wide range of indicators for UGS in the literature, with selection of indicators largely dependent on what is being measured (bio-physical measures, performance measures etc.) and data availability. Moreover, several methods are employed for transforming sets of sub-indicators into an assessable score or performance metrics, or for deriving performance indicators themselves. This section will review the indicators used in the reviewed literature, as well as the dominant methods employed for deriving green space performance measures.

Papers reviewed were first classified by the *broad focus of the paper*, using themes identified in Section 2.3 Literature Review. The aim of this was to identify the most prevalent focus for using UGS metrics and indicators (hereafter indicators) across the reviewed literature.

A parallel classification was also performed *on all indicators found in the reviewed literature*, applying the themes per Section 2.3. The aim of this was to show the prevalence of particular types of indicators across the reviewed literature. We note that while a particular paper's focus may be on UGS quality for example, the indicators applied could be made up of indicators from multiple themes. This highlights the complexity of measuring UGS performance, as well as the interrelationship between many typical indicators of green space performance.

Figure 15 summarises the breakdown of all indicators found in the reviewed literature, which are attached in Appendix G. Quality and quantity were the most prevalent themes of indicators. For quality-based indicators, this reflects the large number of papers where assessing **UGS performance quality** was the focus. For quantity-based indicators, this reflects that bio-physical measures and indicators describing number of trees, or proportion of green cover, are used often across all papers, regardless of the study focus.

Figure 15: Number of Urban Green Space Indicators per Thematic Category

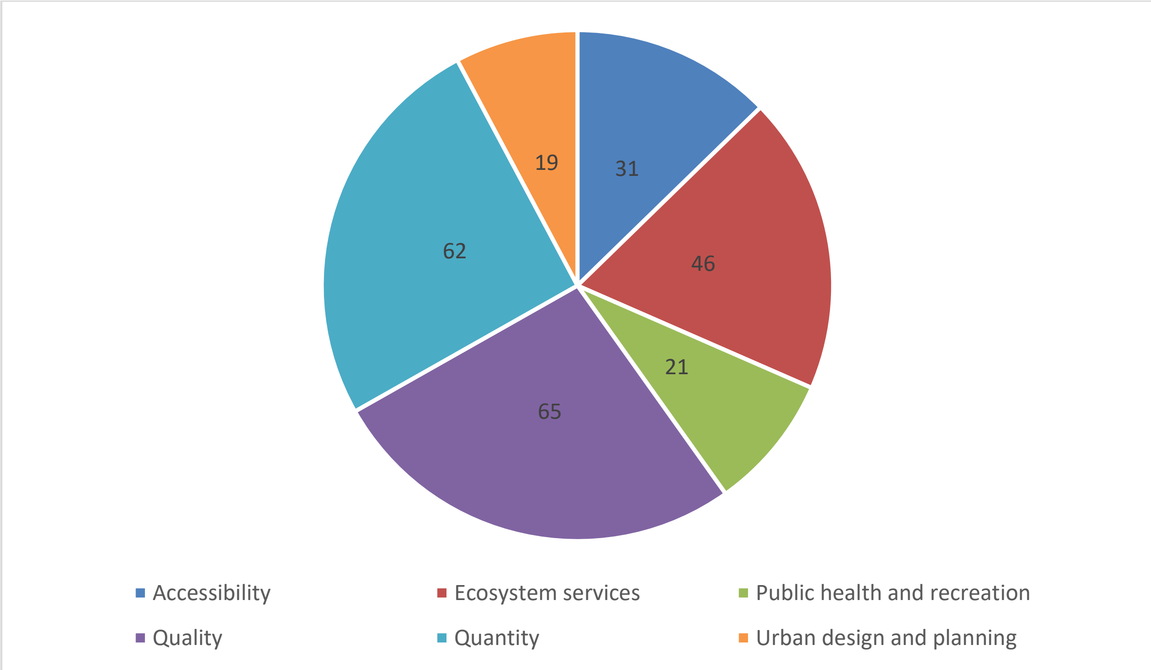


Figure 15 alone does not fully characterise the use of indicators in the reviewed literature as it does not take into account the application of indicators according to a domain or focus. Table 6 below contains a breakdown of indicators in use by the focus of study. Unsurprisingly, indicators relating to a study focus (e.g., accessibility indicators for accessibility focussed studies) are used in greater proportions compared to unrelated indicators across all indicators. Interestingly, quantity-based indicators feature strongly regardless of the focus of the study.

Table 6: Indicator and focus of study

	Indicators					
Focus of study	Accessibility	Ecosystem services	Public health & recreation	Quality	Quantity	Urban design & planning
Accessibility	70%	0%	0%	17%	13%	0%
Ecosystem services	2%	45%	6%	0%	40%	6%
Quality	14%	3%	0%	33%	44%	6%
Urban design & planning	9%	27%	0%	9%	23%	32%
Multiple	6%	16%	16%	41%	16%	6%

3.2.2 Annotated Bibliography

The literature review produced an annotated bibliography. The full text of this annotated bibliography may be found in Appendix I.

3.2.3 Case Studies

The following sections outline selected examples from the academic literature, showcasing how UGS measurement has been conceptualised and implemented in other global contexts. The case studies consist of five city and regional examples from around the world: **Tel Aviv** (Israel), **Delhi** (India), **Beijing** (China), **Stoke-on-Trent** (UK) and **Saxony** (Germany). These neighbourhood, city and regional examples have been selected from a broader range of studies (see annotated bibliography in Appendix I for further information) due to their relatability to the Australian context.

Case Study #1 - Tel Aviv, Israel (soft tool)

Context:

This case study represents a worked example from Cohen et al (2014). Primary publication:

> *A methodological approach to the environmental quantitative assessment of urban parks.* Authors: Pninit Cohn, Oded Potchter, Izhak Schnell. Journal: Applied Geography, vol 48 pages 87-101 Year: 2014

Tel Aviv is a city on the Mediterranean coast, the largest city in the Gush Dan Region of Israel. It is located 32.0853" N, 34.7878"E with a city area consisting of 52 km^2, population of approximately ~430,000 people. Its location on the coast sits it at 5m above sea level with a Mediterranean climate.

Use Situation:

This research presents a **quantitative** methodological approach, incorporating in-situ environmental measurement and data analysis to **evaluate the impact of parks on urban environmental quality**. The primary motivation of this paper was the difficulty in evaluating the overall influence of parks on urban environmental quality. The methodology proposed concentrates on **three environmental nuisances: climate, air pollution, and noise**, which were identified to have the greatest impact on urban park visitors.

The methodology applied includes five stages: in-situ measurement of climatic, air pollution and noise variables; data analysis and indexing; data scaling; accumulative assessment of environmental nuisances, and; grading of overall environmental assessment for specific sites. All data collected was scaled so they could be compared. A grading was applied to assess which nuisance is more impactful in an area under investigation. The results of the application of this methodology show a clear superior environmental quality of parks compared to other urban areas across seasons. The results also show the identification of the nuisances that dominate environmental quality in the chosen investigation sites.

UGS Measures:

This methodology incorporates **environmental-focused indicators** only, reflecting primary drivers of urban environmental quality. The indicators used include air temperature, relative humidity, wind direction, wind velocity, global radiation, net radiation, carbon monoxide, nitrogen oxide, particulate matter, ozone, and noise. Considering findings from other papers, particularly in reference to assessing green space in regards to access and quality of vegetation, the methodology proposed is perhaps deficient as it does not consider these aspects. However, the indicators that are used have a strong connection to urban environmental quality.

Tools:

This case study highlighted a **methodological approach** rather than a tool.

Case Study #2 - Delhi, India (soft tool)

Context:

This case study is a worked example from Gupta et al (2012). Primary publication:

> *Urban Neighbourhood Green Index – A measure of green space in urban areas*. Authors: Kshama Gupta, Pramod Kumar, S.K. Pathan, K.P. Sharma. Journal: Landscape and Urban Planning, vol 105 pages 325-335 Year: 2012

Delhi is India's capital territory, located 28.7041" N, 77.1025"E with a city area consisting of 1,484 km^2, population of approximately ~19 million people. Its shares internal territory borders with Haryana and Uttar Pradesh in the north east of the country, placing it at 227m above sea level. The climate of Delhi oscillates between monsoon-influenced subtropical and semi-arid.

Use Situation:

This paper proposes an **urban neighbourhood green index** to be used as a simple tool, aimed at the objective assessment of UGS and identifying areas for improvement at the neighbourhood scale. The primary motivation of this research was that measures such as percentage of green space or green space per capita are insensitive to **spatial arrangement of neighbourhoods**, e.g., when considering urban densification.

UGS Measures:

The applied method combines several high-resolution spatial data sets to classify vegetation from satellite imagery, as well as buildings. Indicators (% green space, built-up density, proximity to green space, and building height) are calculated, and combined with parameter weights derived through pairwise comparison to form the **neighbourhood green index**. The final output of this analysis is a **mapping suite for UGS quality**, which takes urban neighbourhood structure into account.

Tools:

This paper suggests a relatively straightforward **tool** to assess UGS with consideration of neighbourhood characteristics. However, the tool relies on **complicated analysis and data sets** (i.e., vegetation cover or the estimation of vegetation cover from imagery, and building height information) which may not be readily available to less advanced users. A compromise to incorporate urban neighbourhood structure into a metric for UGS could be the use of a population density metric, rather than raw population to calculate a green space per-capita metric.

Case Study #3 - Beijing, China (soft tool)

Context:

This case study is a worked example from Yao et al (2014). Primary paper:

> *Effective green equivalent – A measure of public green spaces for cities* Authors: Liang Yao, Jingru Liu, Rusong Want, Ke Yin, Baolong Han. Journal: Ecological Indicators vol 47 pages 123-127 Year: 2014

Beijing is the capital of China, located 39.9042" N, 116.4074"E with a city area consisting of 16,411 km^2 and population of approximately ~22 million people. Its location in the north east of the country places the city at 44m above sea level with a temperate monsoon climate.

Use Situation:

This case study example proposes a **metric of effective green equivalent**, defined as "the area of green space multiplied by corrected coefficients of quality and accessibility" (Yao et al, 2014, p123).
As populations increase in urban environments, the availability of private green space diminishes and the need for public urban green spaces increases, and further, within this paper public green space noted as a "public

good" (Yao et al, 2014, p123). Although the overall area is important for accessibility to green space, it is necessary for the public to also **experience the benefit**. Some of the metrics used in this example include the walkability to public green space, and demand on said space due to population increase.

UGS Measures:

This paper proposes a metric of effective green equivalent--a measure of UGS corrected for quality and accessibility. This research is primarily motivated by the deficiencies of the green space-per capita metric prevalent in the measurement of UGS. This study is specifically focused on **public green space**. Therefore the per capita metric is not a sound indicator of UGS performance and accessibility. The indicator developed by the authors considers green space quality and accessibility in relation to residential public green space resources. Three new indicators are developed: **effective green equivalent (EGE)**, **average EGE**, and an **inequality coefficient**. These indicators are then applied to the city of Beijing. The indicators presented in this paper are a function of the area of public green space, its quality and accessibility. Estimates for quality and accessibility are derived from Normalised Difference Vegetation Index (NDVI) estimates and mathematical modelling, relating resident distance to green space.

This paper is useful in the context of the MUGS project as it presents an **adaptable indicator** for evaluating UGS. The indicator is able to provide planners and decision-makers with quantifiable goals with consideration to **both quality and accessibility**, which are sometimes ignored in measuring green space performance. The methodology described can be applied across varied urban localities given the generalisations of the modelling. However, a high degree of mathematical insight and expertise is required. This potentially limits its applicability for decision makers without quantitative backgrounds.

Tools:

This case study highlighted a **methodology** ("soft" tool) rather than a "hard" (software-based) UGS measurement tool. That is, the published study describes a process involving stakeholder participation and expert assessment of neighbourhood green space.

Case Study #4 - Stoke-on-Trent, UK (hard tool)

Context:

This case study is a worked example from Gidlow et al (2014). Primary publication:

> *Development of the Neighbourhood Green Space Tool (NGST)* Authors: Christopher J Gidlow, Naomi J. Ellis, Sam Bostock. Journal: Landscape and Urban Planning vol 10 pages 347-358 Year: 2014

This case study takes place in Stoke-on-Trent, UK, a medium sized town in Staffordshire, northeast England (35.0027" N 2.1794" W). The area is 93 km^2 and population of approximately ~240,000 residents (Gidlow et al, p 248). It is located along the river of Trent which ranges from 350 – 700ft above sea level with a temperate climate.

Use Situation:

There are various ways people interact with natural environments. These include viewing nature (e.g. window), within nature or "passive" use (e.g. walking through a park en-route to another destination) and "active" use (e.g. hiking or gardening) (Ref Pretty, Peacock, Sellens and Griffin 2005). Simply looking at nature through a window has been proven to have positive wellbeing effects (Gladwell et al 2012). Van Dillen et al (2011) noted a quality element, outlining that the space must be sufficiently aesthetically pleasing and safe for the visitor.

This case study undertook two phases: firstly focus groups with local residents followed by a survey completed by interviewees regarding views and experiences of green spaces.

UGS Measures:

GIS data and site visits to a particular neighbourhood green spaces allowed these researchers to garner metrics around **general accessibility**, **recreation facilities amenities**, **natural qualities maintenance**, **signage**, **total size**, **buildings and structures,** and **overall usage and function** (Gidlow et al, 2012 p352).

Tools:

The **Neighbourhood Green Space Tool** (NGST) builds on a tool developed by Foster et al (2006) as a template. This was "intended for simple inspection by independent observers to make quality judgements based on appearance, maintenance, and the presence and quality of various features."

Case Study #5 - Saxony, Germany (hard tool)

Context:

This case study is a worked example from Frank et al (2013). Primary publication:

> *Assessment of landscape aesthetics – Validation of a landscape metrics-based assessment by visual estimation of the scenic beauty* Authors: Susanne Frank, Christine Fürst, Lars Koschke, Anke Witt, Fraanz Makeschin, Journal: Ecological Indicators vol 32 pages 222-231 Year: 2014

Saxony is federal German state in the east of the country located 51.343479" " 12.387772""E with a city area consisting of 18,420 km^2 and population of approximately ~4 million people. The sea level in the region varies with lower Saxony's lower point being approximately 2.5 metres below sea level and some of the higher ground, being 762m above sea level near upper Harz. Saxony is classified as having a warm and temperate climate.

Use Situation:

This article presents a move to **quantitative assessment** - an objective assessment of **landscape aesthetics**, based on the use of well-known landscape metrics. The primary motivation of this research was that landscape aesthetics are perhaps the least formalised issue in the assessment of ecosystem services, as aesthetics cannot easily be quantitatively measured due to the subjective nature of aesthetics.

This paper is useful as it presents a method for measuring landscape aesthetics. While aesthetics are important, they are not necessarily considered in other papers, potentially due to the subjective nature of beauty. If aesthetics is desired to be included in the measurement of Australia's urban green spaces, this paper presents a possible approach for its measurement.

UGS Measures:

The approach presented in this paper uses three landscape metrics: **vegetation shape index**, **Shannon's diversity index** (species diversity), and **patch density**. These metrics were transformed on a qualitative scale as an assessment of positive or negative impacts of the landscape's aesthetic value. To validate the objective approach, a questionnaire was also conducted to assess aesthetics.

Tools:

This example used the framework of GISCAME (GIS= geographic information system, CA = cellular automaton, ME = multi criteria evaluation), a landscape metrics-based assessment method encapsulated in a software platform (Furst, 2012).

3.2.4 Worked Australian Example: Satellite Mapping of Green Space Assets

The worked example described in this section was developed in an addition to the 5 global case studies above. The aim of this worked example is to demonstrate a method (i.e. a soft tool) that 1) is relatively easy to implement (i.e. rapid assessment approach) 2) uses an Australian data set (i.e. produces UGS maps for Australia) 3) serves the purpose of illustrating the decision support framework as depicted in the blueprint (Appendix J).

In this case study, we used a satellite '*greenness*' product known as the enhanced vegetation index (EVI) that combines measures of chlorophyll activity (red spectral image) with a near-infrared image to generate a quantitative measure of greenness that can be used to map UGS. We applied the EVI equation to the European Space Agency's Sentinel-2 satellite[3], to map Australian cities at 10m grid cells.

Defining green space in Australia

Two satellite images, both acquired on 26th of December 2016, were downloaded to cover the Sydney region from the US Geological Survey Earth explorer website[4]. The data were atmospherically-corrected and converted to surface reflectances using the version 3.1 'sen2cor' applications available through the Sentinel Application Platform (SNAP). Using ArcGIS v10.4 (ESRI Inc., 2010), the atmospherically-corrected bands of images were used to compute the two-band Enhanced Vegetation Index (EVI2), using the formula:

$$EVI2= 2.5*((NIR-Red)/ (NIR+2.4*Red+1))$$

where NIR is the near infrared band and Red is the chlorophyll-absorbing red band in the satellite image. The two images of EVI2 were then mosaicked into one image to cover the Sydney region. Geospatial data of boundaries was obtained from Australian Bureau of Statistics (www. abs.gov.au). Using GIS tools, a digital Sydney boundary was extracted from shapefile: Australian Standard Geographical Classification (ASGC) Urban Centres and Localities (UC/L) Digital Boundaries, Australia, 2011. This data identifies the main urban centres or localities of Australia[5]. The boundaries of suburbs, parks and golf courses in Sydney were extracted from dataset: Australian Statistical Geography Standard (ASGS): Volume 1 - Main Structure and Greater Capital City Statistical Areas, July 2016. This data identifies landscape cover areas and mesh blocks in each state of Australia[6]. We also used the geospatial data of Geoscience Australia to recognize names of each of our study areas such as parks and golf courses[7]. Finally, the gridded data of EVI2 were clipped to the boundaries of our interest and data was extracted for further analyses.

As an initial characterisation of green space, we tested different thresholds of EVI2 values (scale is 0-1) to assess total green space and its grass and tree space components. As a quick validation method, we compared our generated maps derived at 10-m pixel resolution, with Google Earth imagery available at 1-m resolution, rather than conduct our own field-based validation protocol. Although Google Earth provides 'commercial' imagery at finer resolution, there are no controls on the dates of acquisition (time of year, and which year), hence it has limited value for mapping of green space metrics.

Using a first order threshold approximation to separate trees from grasses, we found that EVI2 values less than or equal 0.25 mostly define infrastructure; EVI2 values greater than 0.25 and less than 0.45 generally depicted tree areas; and EVI2 values greater than 0.45 represented actively-green grass areas. In Figure 16, the first map (left) shows Sydney area from Google Earth (Source: Google Earth, December 14, 2015). The second map (right) shows 10-m EVI2 values derived from Sentinel-2 images acquired 26 December 2016. Grey areas are

[3] www.esa.int/Our_Activities/Observing_the_Earth/Copernicus/Sentinel-2

[4] https://earthexplorer.usgs.gov/

[5] www.abs.gov.au/ausstats/abs@.nsf/Latestproducts/7D88D2916BF4BBE3CA257A980013999D

[6] www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/1270.0.55.001July%202016?OpenDocument

[7] www.data.gov.au/dataset/sydney-special-1-250-000-gis-dataset

‘No-Green’ places including infrastructure, soil and water; dark green are trees and light green is grass.

Figure 16: Map of green space in urban Sydney

Figure 17A-C provides maps of green spaces and neighbourhoods in Sydney for Liverpool golf course (A), Olympic and Bicentennial parks (B), and Hornsby suburb (C). The maps show EVI2 values from Sentinel-2 image (Top), and from Google Earth images (Bottom) for each area of interest. Grey areas are No-Green space; dark green are trees and light green is grass. Google Earth Images (Source: “Liverpool Golf Course.” 33°54'22.16"S 150°58'18.96"E., October 10, 2015); “Bicentennial Park and Sydney Olympic Park.” 33°50'51.59"S 151°04'20.97"E., October 6, 2015); “Hornsby.” 33°41'57.50"S 151°06'03.90"E., October 16, 2015).

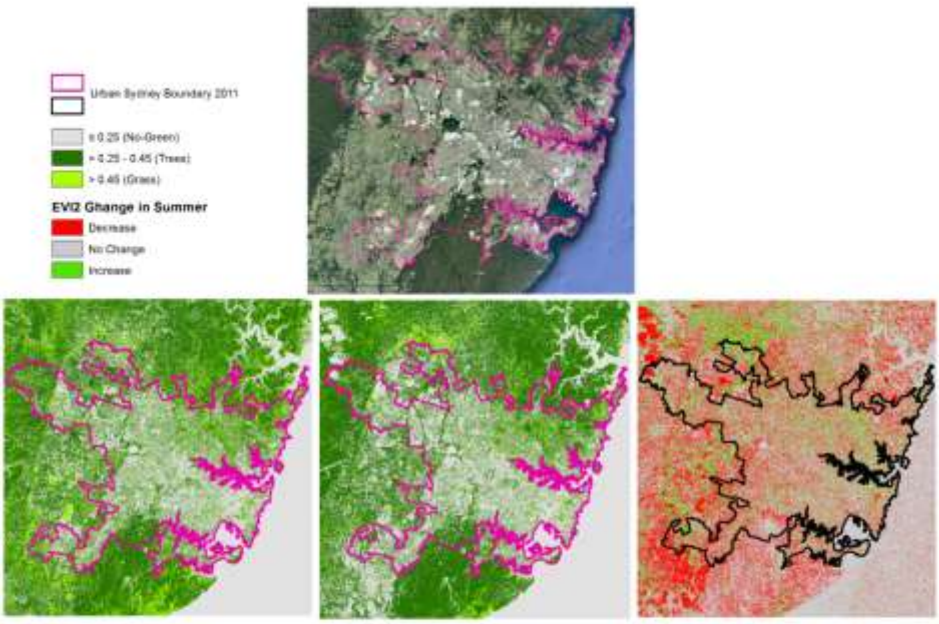
Figure 17: Map of green spaces and neighbourhoods in Sydney

We can zoom in to major green space areas in Sydney to better assess satellite image capabilities in identifying and characterising green space areas Figure 17A-C shows different 'green space' landscapes in Sydney, including Livermore golf course, Olympic and Bicentennial parks and Hornsby suburb. Generally, these results show good agreement between the 10-m maps generated using EVI2 thresholds and 1-m Google Earth images. However, some green spaces were not successfully defined using one set of EVI2 thresholds. For example, grass areas that were partly senescent (dry, non-green grass) resulted in lower EVI2 values of equivalent magnitude as the trees, hence confusing and causing mis-classification of grass from trees. On the other hand, some trees were particularly vigorous (as near washes) and were falsely classified as grass. Overall, these results show that it is feasible to quickly map green spaces with 10-m Sentinel-2 data, however, there are finer issues regarding the correct grass-tree partition thresholds along with possible phenology[8] dynamics issues (senescence) that must be incorporated into a green space metrics scheme, as will be further shown in the next section.

Testing seasonal green space definition and metrics

The goal of this step is to test the extent to which green space assets will vary seasonally, particularly dynamic green grass areas and non-evergreen trees. Such seasonal variation will indicate that any green space metric derived at local, district and city scales will be different if assessed in different months, and hence will be sensitive to time of year that such measurements are made, whether from satellites or from airborne and field-based techniques. Here we conducted a simple comparison test of summer vs winter over the Sydney region. We compared Sentinel-2 imagery from 26 December 2016 (summer) and the 8 August 2016 (winter) by applying the same thresholds and processing of EVI2 values and visually compared these images at whole Sydney scale and for specific zoom areas of interest (golf course, parks and suburb) using Google Earth imagery to guide interpretations (Figure 18). We quantified the seasonal differences in green space by subtracting the winter EVI2 values from EVI2 summer values over the Sydney region and mapped the extent of 'change' in green space (Figure 18). In Figure 18, the bottom maps show EVI2 values from Sentinel-2 images in summer (December 2016) (left), winter (August 2016) (middle), and change in green space between the two (right) represented by derived EVI2 values of satellite images. Grey areas are No-Green space; dark green is trees and light green is grass. Change is represented as seasonal increases (green), decreases (red) and no change (grey). Map from Google Earth (top) shows green space in Sydney region in December 2015 (Source: "Sydney." 33°54'13.13"S 150°48'57.18"E. Google Earth. December 14, 2015).

Figure 18: Map of green space in urban Sydney area through two different seasons



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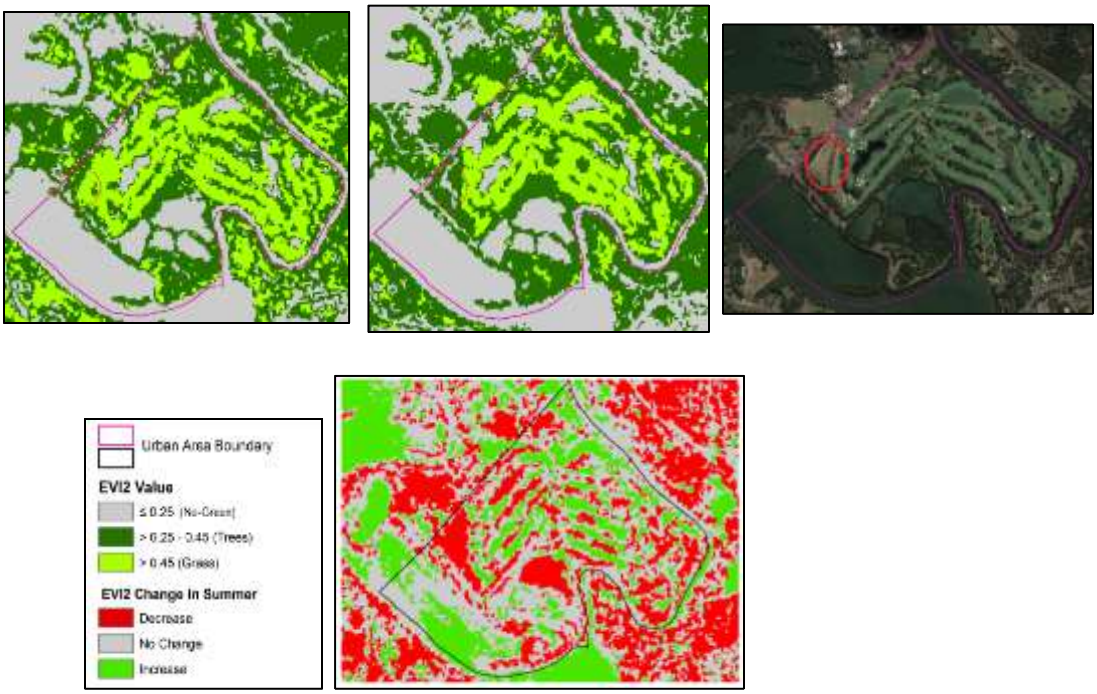
[8] Phenology is the study of cyclic and seasonal natural phenomena in relation to climate and plant and animal life.

In Figure 19 - 21 below, the zoom-in areas of interest are shown in more detail. In most cases, green space definitions were consistent between seasons, however their separation into trees and grass were not always consistent. Defining green areas throughout the year using simple thresholds were not successful for many green places because plant canopies change during different seasons, particularly grasses that can vary in greenness considerably over the year, depending on whether they are warm-season or cool-season grasses and associated phenologies. Certain trees may also seasonally vary, particularly if they are deciduous or brevi-deciduous species or are part of ground-water dependent ecosystems (GDE's).

In Figure 19, the upper maps show EVI2 values from Sentinel-2 image EVI2 values in summer (December 2016) (left), winter (August 2016) (middle) and Google Earth image (right). Grey areas are No-Green space; dark green are trees and light green is grass. Red circles show changing of some areas between summer and winter. Bottom map shows change in EVI2 values in summer (subtracting winter from summer), represented as increase (green), decrease (red) and no change (grey). Map from Google Earth (top) shows green space in urban Liverpool golf course (Source: "Liverpool Golf Course." 33°54'22.16"S 150°58'18.96"E. Google Earth, October 10, 2015).

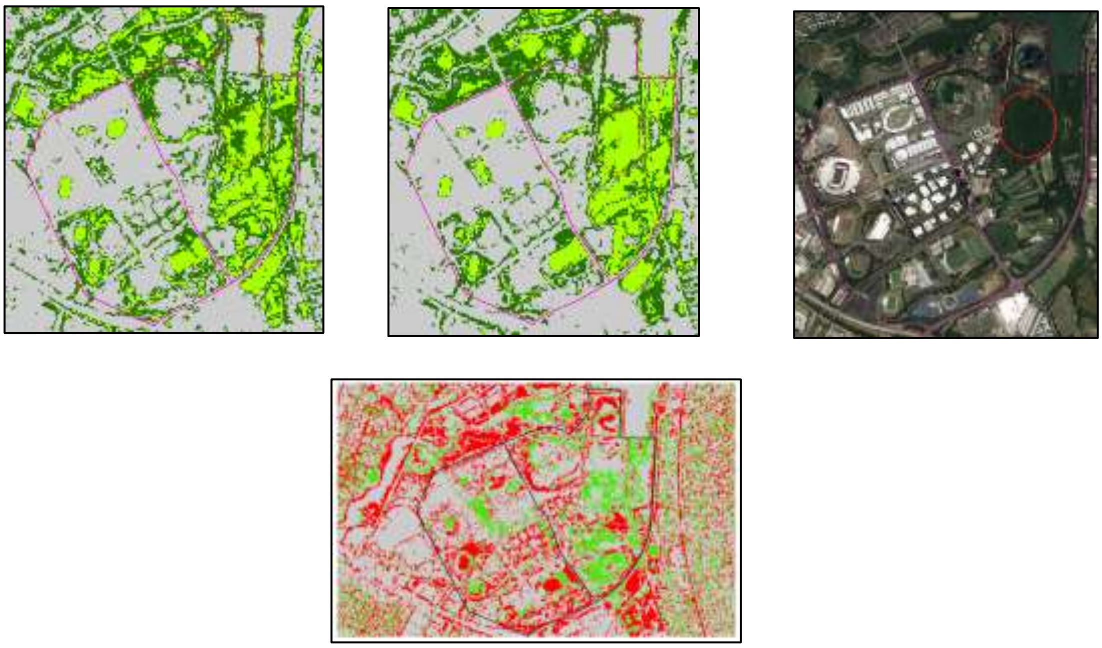
Figure 19: Map of green space in Liverpool golf course through different seasons



Using the fixed EVI2 thresholds to distinguish between grass and trees will lead to some failure because the thresholds themselves would seasonally vary, according to the phenologies of the tree and grass species. As examples, in Liverpool golf course (Figure 19), some grass is defined as grass and trees in winter (red circle in the image), whereas it's defined as trees in summer. This is because grass gets drier in summer and thus has a lower EVI values that caused them to be classified as trees. In Bicentennial and Olympic parks (Figure 20), some areas of trees are defined as trees and grass in winter and as grass in summer. This is because these trees became greener in the summer with higher EVI values that caused them to be classified as grass in neighbourhood areas such as Hornsby suburbs. In Figure 21, the upper maps show EVI2 values from Sentiel-2 image EVI2 values in summer (December 2016 – left), winter (August 2016-middle), and Google Earth image (right). Grey areas are No-Green space; dark green are trees and light green is grass. Red circles show changing of some areas between summer and winter. Bottom map shows change in EVI2 values (Subtracting winter from summer), represented as increase (green), decrease (red) and no change (grey). Map from Google Earth (top) shows green space in Hornsby (Source: “Hornsby.” 33°41'57.50"S 151°06'03.90"E. Google Earth. October 16, 2015). Figure 21, trees are defined as no- green or grass in winter, whereas these trees are defined as trees in summer. This is because these trees became greener in the summer with higher EVI values.

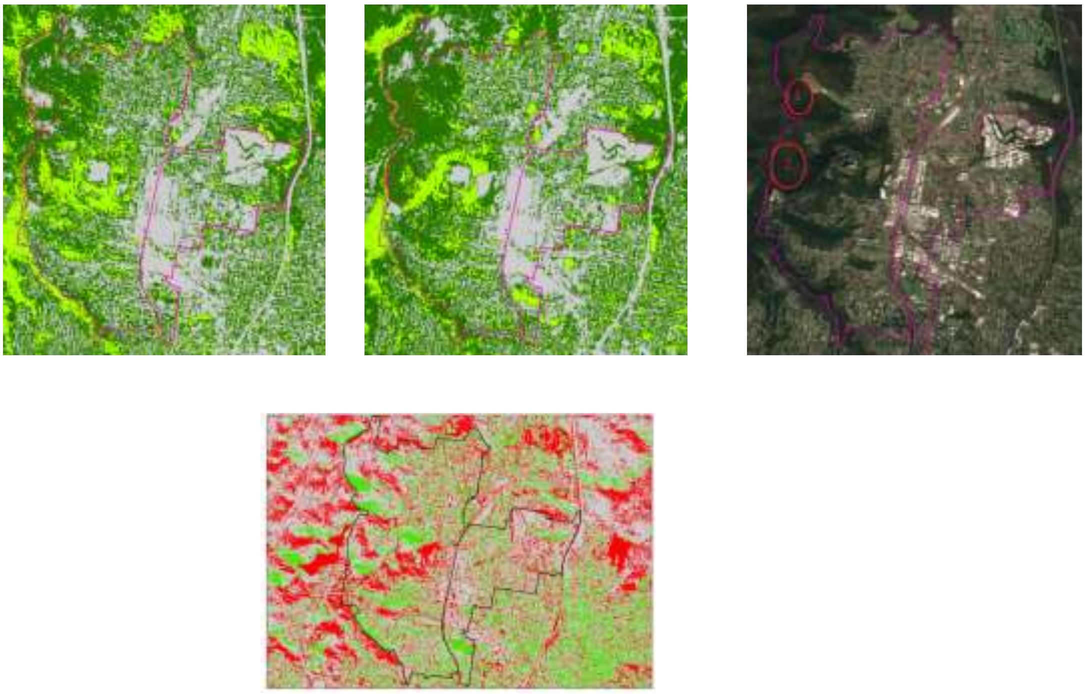
In Figure 20, the upper maps show EVI2 values from Sentinel-2 image EVI2 values in summer (December 2016) (left), winter (August 2016) (middle) and Google Earth image (right). Grey areas are No-Green space; dark green are trees and light green is grass. Red circles show changing of some areas between summer and winter. Bottom map shows change in EVI2 values in summer (subtracting winter from summer), represented as increase (green), decrease (red) and no change (grey). Map from Google Earth (top) shows green space in the Parks (Source: “Bicentennial Park and Sydney Olympic Park.” 33°50'51.59"S 151°04'20.97"E. Google Earth, October 6, 2015).

Figure 20: Map of green space in Bicentennial and Olympic parks through different seasons



In Figure 21, the upper maps show EVI2 values from Sentinel-2 image EVI2 values in summer (December 2016) (left), winter (August 2016) (middle) and Google Earth image (right). Grey areas are No-Green space; dark green are trees and light green is grass. Red circles show changing of some areas between summer and winter. Bottom map shows change in EVI2 values (subtracting winter from summer), represented as increase (green), decrease (red) and no change (grey). Map from Google Earth (top) shows green space in Hornsby (Source: “Hornsby.” 33°41'57.50"S 151°06'03.90"E. Google Earth. October 16, 2015).

Figure 21 Map of green space in Hornsby suburb through different seasons



Seasonality Conclusions: Although seasonality in Green Space Assets may potentially confound quantitative comparisons of changes in Green Space over space and time, it also provides the opportunity for new metrics of urban green space. For example, being able to map 'Duration in Greenness' is in itself a valuable metric, as this will help define the length of time a Green Asset is actually green, as would be the case for neighbourhood parks that can quickly change from an aesthetically valuable green space asset to a less desirable dry/ brown grass area of lesser aesthetic appeal for recreational activities. Similarly, phenologic cycles of greenness and browness/ dryness are of value in determining fire fuel loads, hazards, and fire vulnerability. Green space phenology is also of interest to pollen forecasting and flowering seasonal events.

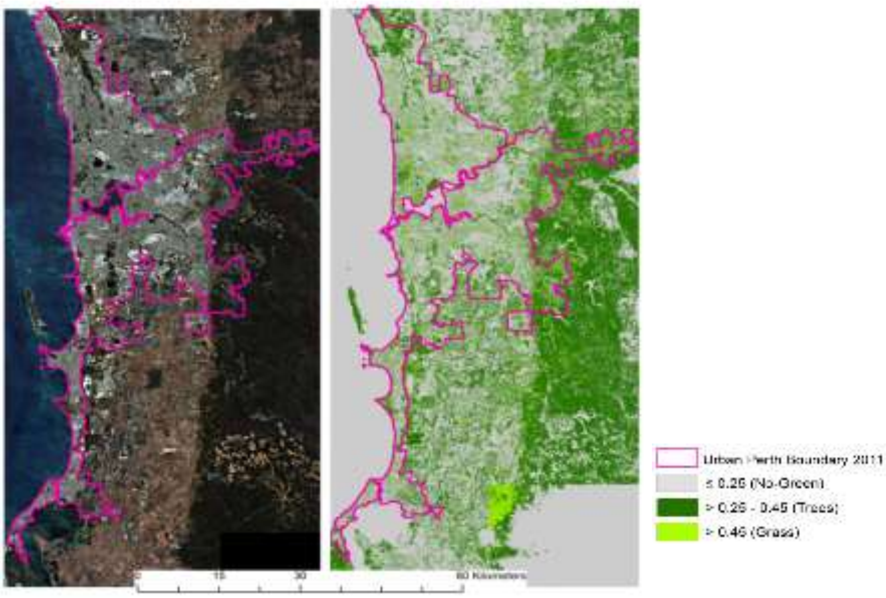
Testing satellite green space measures across different cities

In this test we assess whether the satellite based green space approach can be applied to other Australian cities. We applied same satellite-based approach and processing used for Sydney on Melbourne and Perth (Figure 22 and Figure 23). Overall we found that this tool is quite useful for rapid mapping of basic city-wide green spaces. In Figure 22, the map on the left is a true colour Sentinel image of Melbourne, while map on the right shows EVI2 values from the same Sentinel image. Grey areas are 'No-Green' places including infrastructure, soil and water; dark green are trees and light green is grass.

Figure 22: Map of green space for Melbourne with Sentinel EVI2, 12 December 2016

In figure 23 the map on left is a true colour Sentinel image of Perth, while map on the right shows EVI2 values from the same Sentinel image. Grey areas are 'No-Green' places including infrastructure, soil and water; dark green are trees and light green is grass.

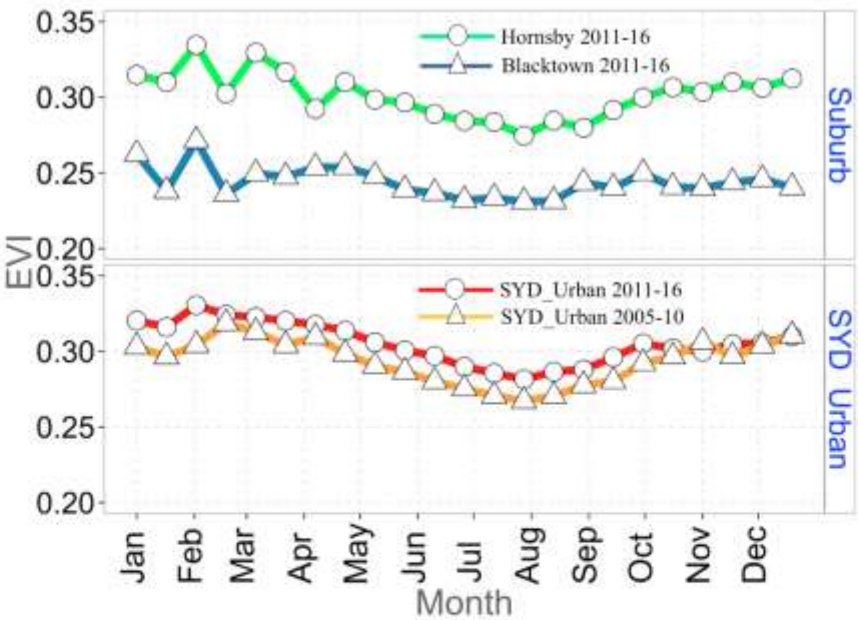
Figure 23: Map of green space for Perth with Sentinel EVI2, 8 December 2016. Map on the left is true colour Sentinel satellite image of Perth; Map on right shows EVI2 values from same Sentinel satellite image.



Testing urban green quality concepts

Ideally, cities wish to improve the quality, as well as quantity, of their green space assets, particularly in neighbourhood areas. Urban green space quality can be measured in numerous ways and from different aspects. Here we show comparisons of green space across Sydney neighbourhood councils as well as over 5 year time periods to investigate spatial heterogeneity in green spaces within a city, as well as to assess trends over time.

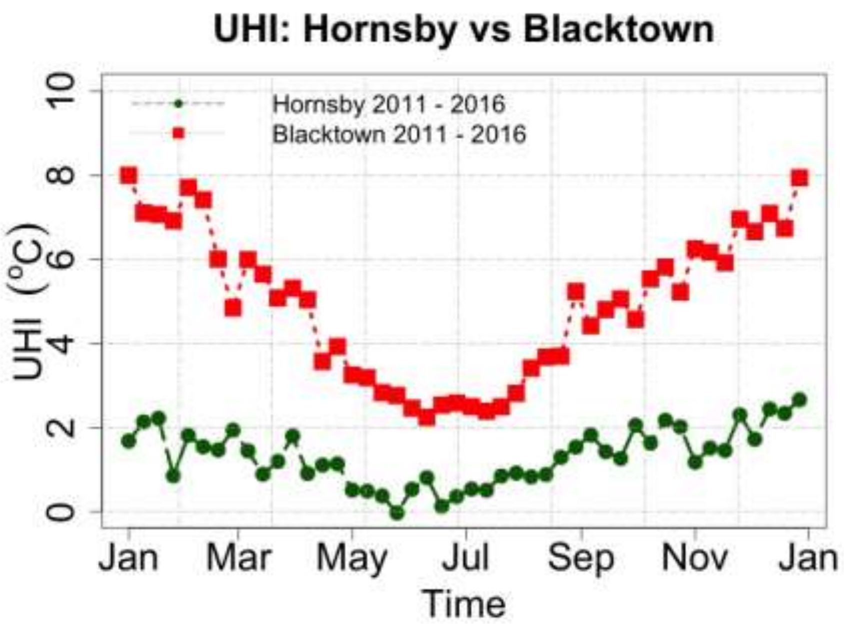
Figure 24: Mean seasonal EVI values (2011-2016) between Hornsby and Blacktown councils in Sydney (top); and comparison of whole Sydney urban area over two time periods (2005-2011 & 2011-2016) (bottom)



We derived such quick assessments using Moderate Resolution Imaging Spectroradiometer (MODIS) satellite data to measure green space quantity and duration between Hornsby and Blacktown councils in Sydney (Figure 24). As seen in Figure 24 (top), Hornsby suburb area is much greener than Blacktown suburb area. Hornsby also has much more dynamic seasonal greenness dynamics relative to Blacktown which exhibits little change in greenness throughout the year. In the comparison made over Sydney between two separate 5-year periods Figure 24 (bottom) one sees that there was an overall gain in green space over Sydney region between the 2 time periods. Such coarse scale assessments are quite objective, consistent, and robust, however one needs to consider and possibly remove any 'climate signals', i.e., to ensure that wetter periods with more lush vegetation didn't influence the assessment of the aerial coverage of green space metrics. This consideration is similar to the potential seasonality influence on derived green space metrics and can be taken into account with more sophisticated green space modelling approaches.

Lastly, we show one last practical example of urban green quality that is related to the Urban Heat Island (UHI) effect that has potential consequences to extreme heat events and human health as well as verifiable assessments of the living quality of neighbourhoods. Using land surface temperature measurements from the MODIS satellite, we compare the UHI effect in Blacktown to that in Hornsby.

Figure 25: Seasonal mean Urban Heat Island (UHI) values over 5 years (2011-2016) in Blacktown and Hornsby suburbs



These quick assessment results show that the greener suburbs have a direct influence in cooling neighbourhoods and minimizing the UHI effect Figure 24 and Figure 25. The low extent of green space in Blacktown result in significantly warmer temperatures and much higher UHI effects relative to Hornsby suburb. Any council that acts to increase their green space assets will want to have verifiable and evidence based outcomes, both of which can be provided by these satellite-based metrics of green space assets. Similar analyses can be done at the city block scale, thereby relating green space metrics with thermal environments and public health, for any specific times of the year as well as for extreme heat events.

3.2.5 Tools identified within literature review

Table 7 below provides an overview of tools that have been found across the literature, or were known to project researchers before the commencement of the project.

Table 7: Overview of tools from literature review

Name of tool (hard/soft)	Focus	Application	Scale	Limitations
iTree (hard)*	Bio-physical measurement	Estimating proportion land-use category (e.g., vegetated areas)	Up to neighbourhood scale	Heavily resource intensive. Questionable robustness.
Urban Atlas (hard)	Bio-physical measurement	Detailed database of land cover for EU	Up to 1m resolution (city scale max)	Only contains small number of land use classes (e.g., green space). Questionable robustness of derivation of land use classes. Not ultra-fine scale. EU only.
Public Open Space Desktop Auditing Tool (soft)*	Asset management and bio-physical measurement	Desktop tool for assessing quality of public open space assets and infrastructure	Fine scale	Possibly less accurate than in-situ methods. Relies on a complicated set of indicators that require other tools to quantify
Melbourne Urban Forest Visual (hard)	Asset management	Online visualisation platform of City of Melbourne catalogue of urban trees (genus and lifecycle)	Fine scale (individual tree level)	Only for quantifying number of trees and species diversity. No estimation of other metrics. Can be combined with other data sets
Neighbourhood Green Space Tool (soft)	Quality assessment	Tool for assessing the quality of neighbourhood green space against a set of indicators	Neighbourhood scale	More of a methodology than a tool. Relies on other tools for quantifying metrics
Sentinel Application Platform (SNAP) (hard)	Remote sensing	Platform for processing remote sensing data, including derived vegetation indices. As a tool, can be used for quantifying metrics	Up to city scale	Requires advanced expert knowledge. Not ultra-fine scale.

Name of tool (hard/soft)	Focus	Application	Scale	Limitations
		from remote/satellite data		
Coordination of Information on the Environment (CORINE) (hard)	Global land use classification	Tool comprising of global NDVI estimates from remotely sensed data, that can be incorporated into other metrics	Regional scale	Not applicable to neighbourhood scale. Reduced usefulness for city scale due to resolution.

*Also identified by interviewees

3.3 Phase III - Blueprint

Based on the research undertaken in Phases I and II of this project, an Australian decision-support framework for best practice UGS planning and management was then conceptualised during Phase III. Throughout the project, the notion of "tools", or "a tool" generated lively discussions, both within the research team and in our interactions with Hort Innovation and our Project Advisory Group (PAG). In Section 1.2 Tools for Measuring UGS an explicit distinction is made between UGS **analytical tools** ("soft" methodologies and "hard" software implementations) – of which there are many – and a **decision-making framework** for UGS in Australia. Whilst it may be possible to develop a customised analytical tool for quantifying pre-defined UGS measures, our findings suggest that a decision-making framework would have stronger innovative potential, stand a higher chance of adoption and moreover could be implemented more feasibly. Whilst the blueprint highlights the innovative potential of a decision-making framework, a business case would need to be developed to further maximise the likelihood of adoption. Also, further research will be required to assess the feasibility of implementation.

In summary, our findings suggest that a nationally consistent decision-support framework for best-practice UGS planning and management would need to include the following key features:

1. Multiple and flexible **user entry points** to accommodate 1) different use situations (types of UGS decisions that require quantitative decision support); 2) different thematic categories of UGS measures; and 3) immediate access to existing analytical capacity;
2. A broad baseline of **analytical capacity**, with pointers to existing 'soft' tools (documented/published methods) and 'hard' tools (implemented software); whilst the framework may be designed to internalise selected existing analytical tools this would greatly complicate its implementation and indeed introduce a risk of 'reinventing the wheel'.
3. A (heuristic) **decision tree** to help users decide – based on their entry point (per key feature 1 above) on which UGS measures and tools to use in response to a particular problem;
4. **Multiple tiers** of analytical complexity (e.g. comprehensive biodiversity assessment vs rapid assessment of tree presence);
5. Capacity to allow citizen science/participation as well as national benchmarking;
6. A worked example of how the framework can be used to produce metrics.

The blueprint intends to visually communicate these key features. The blueprint was designed with an informed and technically trained audience in mind, and with a view to drive further demand for an implemented decision-support framework for UGS planning and management. As such, it is both a technical summary of findings from the project and an outlook.

An initial sketch was developed based on a story board design. We sought the PAG's feedback on this sketch as to whether:

1) The above features are adequately represented in the sketch;

2) The sketch is clear and convincing as a stand-alone document intended to drive demand for an Australian decision-support framework for best practice UGS planning and management;

3) The 'selling power' of the blueprint would be enhanced by adding a detailed worked Australian example (per Section 3.2.4 Worked Australian Example: Satellite Mapping of Green Space Assets).

Feedback from the PAG made it clear that the initial sketch did not communicate well as a stand-alone document. The design was therefore simplified and the storyboarding made more consistent so that the six panels on the blueprint can be read as a story:

1) Urban green space – growing towards best practice planning and management in Australian;
2) Decisions - UGS decisions have a variety of entry points;
3) Measures – UGS measures are grouped thematically;
4) Tools – tools range from published methods to coded software;
5) Decision-support framework;
6) Using the decision-support framework in three steps.

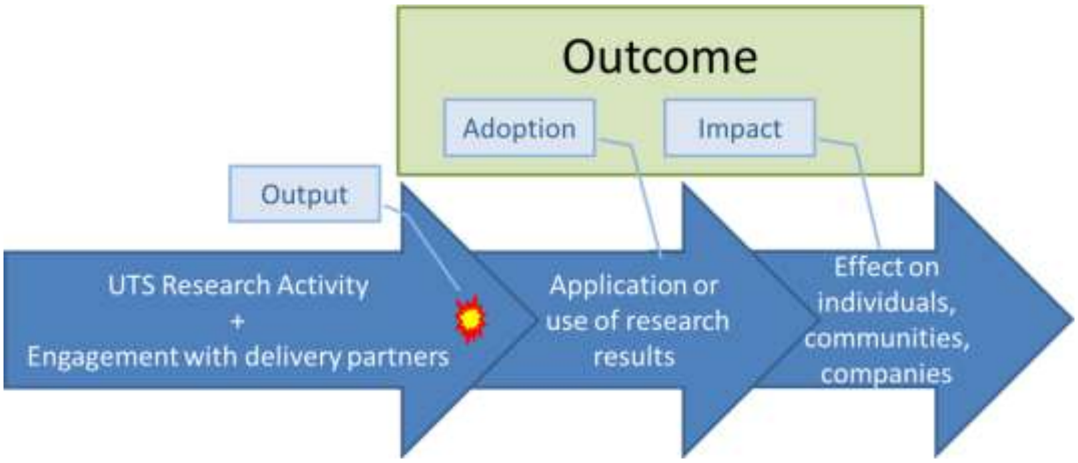
The blueprint is provided in Appendix J and makes reference to a one-page summary of the worked Australian example "Satellite Mapping of Green Space Assets" (Appendix K).

4. Outcomes

Chapter 3 detailed a rich array of *outputs* from the research undertaken in this project. However, as this project was commissioned as an exploratory pilot to explore the needs and demand for a nationally consistent approach for measuring UGS, it is not yet possible to claim project *outcomes* and point to specific evidence of adoption and impact of either the nationally consistent framework itself, or the blueprint that we developed. At this stage the blueprint – the most consolidated output from this project – has not yet been trialled with our broader stakeholder audience.

Therefore we are conservatively claiming an emergent trajectory towards impact, positioning the project results towards the very end of the output phase (Figure 26 – red/yellow dot).

Figure 26: Path to impact from research (Source: UTS Research & Innovation Office)



This project effectively delivered upon the three research questions asked:

- What are the current practices of UGS measurement in Australia?
- What is the current scientific state of the art with respect to urban green space measurement?
- Could a coherent framework, approach or software tool shift current practice in Australia?

The findings from engagement with Australian UGS stakeholders (Phase I) and comprehensive review of methods, approaches and tools as documented in the international scientific literature (Phase II) demonstrate a rich and diverse palette of current practices, needs and future possibilities.

The resulting framework, consolidated as a ‘blueprint’, emerged from both the stakeholder involvement and outputs from the literature review and case studies. This possible nationally consistent approach for the measurement of Australia’s green space asset has been confirmed to address a growing need within the sector.

To date there has been no evaluation of this framework; however the research undertaken were first steps to ascertain market needs and appetite. The blueprint (Appendix J) is a visual representation of the framework, a visual artefact; this blueprint will be presented at national forums (the EcoCity World Summit in Melbourne (July 2017) and the 10th Making Cities Liveable Conference in Brisbane (July 2017); and made available to the public through this report.

5. Evaluation and Discussion

First and foremost, both our interviews and focus groups demonstrated **an obvious interest** in a more consistent, possibly national, approach to the measurement of UGS. However, defining the exact scope and purpose of such a national approach (to which to date the project has loosely referred to as a "tool") was critically important. Whilst many terms were used interchangeably (e.g. trees, green space, open space), most stakeholders had an intuitive notion of what UGS is and what it is not. Yet, despite this intuitive understanding of colloquial terminology, precision of language and clear definition was required when moving from qualitative descriptions to more quantitative approaches.

The research has highlighted a need to make a clear distinction between a **metric** and a **measure**, noting that metrics such as percentage, area, count, or rank are *generic* and can be applied regardless of *what* is measured. In our current context a **metric** should explicitly be considered as referring to "a **system or standard of measurement**; a criterion or set of criteria stated in quantifiable terms" (Oxford English Dictionary). A **measure**, on the other hand, is a **means of measuring**, i.e. "a standard, rule of judgement, etc., against which something may be gauged, determined, or regulated; a criterion, test" (Oxford English Dictionary). A "metric" is most specific (e.g. number of trees – single indicator) where as a "measure" typically comprises a multitude of metrics and is therefore more akin to a composite indicator.

Furthermore, whilst the notion of "**urban green space**" was also mostly intuitive to our interviewees and focus group participants, there remains a question as to whether a nationally consistent approach should have **broad coverage** (including e.g. structural elements of the built environment such as green roofs and green walls) or be **more specifically focused** on the types of green (and open) space that is typically managed by local councils (our main stakeholder group during Phase I).

A key insight from our stakeholder engagement is that the need for a nationally consistent approach is perhaps **greatest among local governments**, with a possible supporting and coordinating role from state and federal government. The commercial sector (developers, landscape architects) also measures various dimensions of UGS; however approaches and methods developed and applied are often for specific projects and are not "codified" in stand-alone software or online platforms for wider commercial gain. To compile a comprehensive inventory of such approaches – which likely employ measures and methodologies documented in the scientific literature – would require an additional effort while being mindful of issues of commercial intellectual property.

When we consider the scope and breadth of the UGS measures that stakeholders nominated in interviews and focus groups we see a consistent pattern. Typically, a core set of measures around quantities of urban **trees and canopy cover** was mentioned (number of trees; canopy cover and volume) before any measures of **use and experience** were mentioned. A second major category of discussed measures can be summarised as **ecosystem services**, or the benefits that nature (ecosystems, trees, UGS) provide to people. Examples include heat mitigation, air quality regulation, the provision of shade and shelter and scenic beauty. A further common theme was the **accessibility** of UGS, especially in the context of the privatisation of public green space (see use situations in Appendix F). In this context discussions also focussed on the need to quantify the loss of public value from the privatisation of UGS. Several focus group participants were particularly interested in measures that could support **asset management** processes. UGS asset managers face a challenge when it comes to articulating the benefits of vegetation relative to their risks (trees falling on people, roots causing damage to other critical infrastructure). A further over-arching theme was the **quality** of UGS. This general category ranged from additional canopy quality measures to measures expressing the (improved) liveability of urban green spaces.

Similar to the findings from stakeholder engagement, our literature review also found a wide range of approaches, methods and use situations. Yet at the core of this rich diversity of approaches is the **measurement of vegetation**, whether it is trees, turf grass, phenology, or flowers. However, the science of UGS measurement appears to be shifting away from pure bio-physical measures, with many studies acknowledging the importance of using **composite (holistic)**

indicators to measure UGS performance. Whilst many measures and associated data calculation procedures exist, there is inherent complexity in selecting indicators as they are inherently context-dependent. This suggests that it may be challenging to create a completely generic set of indicators for measuring Australian UGS (quantity, quality, performance) across different localities and scales.

In this context, it is worth noting that the literature also offers **systematic approaches for *selecting* measures**. A well-known example is cost-benefit analysis. Some studies perform a multi-criteria decision-making framework (e.g., analytical hierarchy process) to derive the most meaningful indicators for measuring green space performance. Such approaches are also amenable to stakeholder input (participatory criteria development).

An exhaustive list of UGS measures identified from stakeholder engagement and from literature is provided in Appendices G and H. Rather than evaluating/screening each of these metrics individually, they can be 'filtered' through consolidated categories. Triangulating the findings from literature review, published case studies, interviews and focus groups results in a series of groupings, or **"frames" in which users come to use UGS metrics**. These frames are:

- **Vegetation management** – quantity and quality of trees, grass, phenology and other types;
- **Asset management** – measures characterising UGS as assets, including risks and benefits;
- **Ecosystem management** – measures addressing the role of urban vegetation in the wider (urban) ecosystem;
- **Urban planning** – spatial relationships between supply and demand of vegetation;
- **Human well-being and liveability** – relationships between presence of vegetation and its use and experience by people.

A cross-cutting theme is the **economic value of UGS**. For example, the measure of "economic value of trees" (i.e. the trees themselves) may be of merit to asset management practitioners whereas the measure of "value of aesthetic pleasure" (i.e. derived *from* trees) may be of merit to practitioners with responsibility for improving urban liveability.

Table 8 below offers a high-level evaluation/screening of the five frame categories in terms of stakeholder priority (as found from interviews and focus groups) and readiness of measures (as found in literature – i.e. a scientific "reality check"). The last column represents an indication of the **innovation potential** if the thematic category were to be featured in a nationally consistent approach for UGS measurement in Australia. Innovation potential refers to the potential to address a knowledge gap. The "Vegetation" category may be seen as the "low-hanging fruit" (with "hard" tools already available); the "Human well-being and liveability" category can be seen as the "holy grail" of UGS measurement.

Table 8: Evaluation of frame categories (*=low; ***=high)**

Thematic category	Expert assessment of stakeholder priority	Readiness of measures	Innovation potential
Vegetation Management	*****	***	*
Human Wellbeing and Liveability	****	*	*****
Urban Planning	***	**	**
Asset Management	***	***	**
Ecosystem Management	**	**	*

Once frame categories are established, a choice has to be made as to what indicators, or composite indicators would best represent the category and would best suit its practitioners. A **multi-tiered approach** may be able to maintain generic applicability, yet offer flexibility to the end user. A hierarchy of indicators could be established, with a "flagship" composite indicator in tier one, a small (2-5) set of key indicators in tier two, and expert-only indicators in tier two. In total about 20 measures could be provided at the level of tier two. Tier three could refer to published sources and online expert tools and could cover as many as 50 metrics.

This complexity is reflected in the Australian worked example demonstrated in Phase II (Section 3.2.4). Using freely available satellite imagery, at 10-m grid (pixel) resolution and 5-day repeat cycle, can be used effectively to undertake cross-site mapping and monitoring. The 10-m data provides a consistent input for measuring green space. The demonstrated method can be applied globally and repeated as often as weekly. More practically, assessment could be repeated at seasonal and inter-annual time scales, thus enabling cross-comparisons of green spaces at district council, neighbourhood block, cross- cities, and historical time increments. The methods outlined within this rapid assessment are readily replicated. This example serves as a mechanism by which relevant issues, concerns, limitations and potential solutions may be explored and resolved. For example, the 10-m satellite imagery may enable mapping of tree stands but not tree species, and thus can be used to confirm the need for acquisition of commercial imagery at finer resolution, whether it be Worldview-3 satellite data at 40cm resolution, or airborne sensor data at 5- or even 1-cm resolution. This granularity of imagery may also be coupled with additional datasets to achieve other higher goals; such coupling of green space metrics with urban heat island or proximal distances to schools, parks, and hospitals.

Based on insights into stakeholder needs and demand, the scientific state of play, and having worked through a series of examples, a rationale for the blueprint of an Australian nationally consistent approach to UGS measurement emerged. The blueprint thus distils the research undertaken into a decision support framework. There are a variety of decisions made about urban green spaces and these decisions pose questions regarding the analytics of UGS. These analytical questions prompt the need for measures that are grouped thematically. From the research undertaken five thematic categories were settled upon. Selection of measures may in turn prompt the need to employ a variety of tools (both hard and soft). The nature of UGS decisions to be made dictates the level of complexity demanded of analysis, and the 'fit for purpose' assemblage of measures and associated tools in order achieve best practice.

Our findings suggest that a **nationally consistent decision-support framework** would have strong innovative potential, stand a high chance of adoption and moreover could realistically be implemented. We note that additionally it may be possible to develop a 'baseline toolbox' for quantifying UGS measures as selected through the decision-support framework.

Whilst the blueprint highlights the innovative potential of a decision-support framework, a business case would need to be developed to further maximise the likelihood of adoption. Also, further research will be required to assess the feasibility of implementation.

6. Recommendations

- Among the stakeholders consulted **there exists a clear need for a nationally consistent approach** for the measurement of Australia's green space asset.
  RECOMMENDATION 1: that such an approach is developed based on the blueprint from the current research.

- A nationally consistent approach for urban green space measurement would be **of primary benefit to local councils and state governments**. The commercial sector is likely to employ approaches that were developed in-house for specific (commercial) purposes.
  RECOMMENDATION 2: that a nationally consistent approach be targeted towards local and state governments.

- The **measures used currently and sought for future use** are fairly consistent across jurisdictions. The specific **contexts of application vary greatly** across jurisdictions and policy domains (urban forestry, asset management, climate change adaptation).
  RECOMMENDATION 3: that the diversity of entry points for decision-support be researched further, for example in pilots with local councils.

- Whilst many different measures have been, and are being researched, **"hard" tools (software packages or platforms) are still hard to come by** in the scientific literature. Published studies typically employ "soft" tools more akin to methodologies of analysis.
  RECOMMENDATION 4: that existing soft and hard tools are researched in more detail to assess whether there could be a 'baseline toolbox' for specific use in conjunction with the proposed decision-support framework.

7. Scientific refereed publications

None to report. Two peer-reviewed articles are currently being planned.

8. Intellectual property/commercialisation

No commercial IP generated.

9. Acknowledgements

The Institute for Sustainable Futures would like to acknowledge and thank all interviewees, focus group participants and Project Advisory Group members for volunteering time to participate in this research. We thank ISF colleague Associate Professor Brent Jacobs for his expert advice.

10. Appendices

- Appendix A: Interview Questions
- Appendix B: Focus Group Run Sheet
- Appendix C: Interview Methodology
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- Appendix G: Metrics from Literature
- Appendix H: Metrics from Focus Groups
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- Appendix K: Rapid Assessment of Urban Green Spaces

Appendix A Interview Questions

Introduction

For the sake of the recording, can you please state:

- Your full name
- The name of your organisation
- Your position title in the organisation

How long have you been working in this sector, please choose from the following?

<1 year
1-5 years
5-10 years
>10 years

How experienced would you consider yourself in the field of urban green space planning and management on a scale of 1-5 with 5 being very experienced and 1 being not experienced at all?

Not Experienced				Very Experienced
1	2	3	4	5

Metrics

What metrics and indicators do you currently use for measuring urban green space?

Do you have any memorable successes or failures, for example the use of measures that resulted in positive or negative outcomes?

Have you experienced any particular gaps in urban green space metrics?

Do you find current metrics are compatible with other approaches to urban planning?

IF TIME:

Can you give us your top of mind “Do’s and Don’ts” for measuring urban green space?

Is there a need for different and/or more comprehensive methods for the planning and management of urban green space?

Tool format

If a measurement tool is developed for urban green space in Australia, which of the following formats would be useful?

	Yes	**Maybe**	**No**
Stand-alone software e.g. Excel, GIS			
Online tool			
Other? (please describe)			

Which of the following approaches for a tool would be most useful?

	Yes	**Maybe**	**No**
Qualitative Guidebook (e.g. with principles/steps)			
Quantitative model (e.g. with calculations)			
Other? (please describe)			

How about how the tool is used, which of the following would be most useful?

	Yes	**Maybe**	**No**
Use the tool in-house			
Share the tool with other users			
Other? (please describe)			

Do you currently have any resources or materials relating to urban green space metrics in your region that you could you share with us?

Closing:

Is there anyone else that you think we should talk to regarding this project?

[If yes, obtain contact details]

Would you be interested in participating in a half-day focus group in your nearest city?

[If yes, ask which city is best and if any times suit best]

Do you have any final questions or comments?

Would you like to see a transcript of this interview?

Thank you very much for your time. We look forward to keeping in touch.

Appendix B Focus Group Run Sheet

Time	Mins	Cml	Activity
13:00 – 14:10	10	10	Welcome and overview of the program
13:10 – 14:20	10	20	Participants' introduction & icebreaker
13:20 – 14:20			**ACTIVITY I: What metrics / indices**
	10	30	Introduction and explanation
	10	40	Individual work - Write 5-10 metrics on Post-Its (add initials!!)
	20	60	GROUP WORK - Affinity mapping: clustering of themes - Themes on butchers paper – take their metrics and indices & stick onto themes
	20	80	compare – work with grouping
14:20 – 14:30	10	90	Break – tea & coffee
14:30 – 15:30			**ACTIVITY II: Application of metrics**
	10	100	Introduction and explanation
	40	140	GROUP WORK - Based on your professional experience: think through 2 (or 3) situations where UGS metrics can improve the status quo Think across: - Scale - Policy domain - One off, or ongoing - Where is current practice - Where is the opportunity for improvement towards best practice?
	10	150	Reflection
15:30 – 15:50	20	170	Discussion – prototyping the tool (input for blueprint) - What benefit? - Who should be custodian? - Data sharing? - Skills & capacities? - Policy barriers
15:50 – 16:00	10	190	Wrap-up

Appendix C Interview Methodology

Stakeholders were selected for telephone interviews based on if they were:

- Involved in urban green space planning from industry, state or local government;
- Experienced with, or interested in, existing and potential urban green spaces in Australia ;
- Involved in measuring (including mapping), regulating, developing or promoting urban green space projects;
- Able to provide perspectives on urban, peri-urban and suburban green spaces nationally;
- Representative of disciplines involved in green spaces such as urban planner, horticulturalist, ecologist, scientists, geospatial analyst, GIS specialist, landscape architect, health professional, policy-maker and public servant.

We sought to interview stakeholders located across Australia, a range of sectors and located in the urban areas of the country. Recommendations for appropriate interviewees and contact details were obtained through Hort Innovation, members of the project's Project Advisory Group, ISF's own networks and recommendations from interviewees as the interviews progressed. shows 16 stakeholders completed interviews across 15 organisations (1 organisation had 2 interviewees).

Table C 1*: Phase I Interviewees*

#	Sector	Organisation	Location
1	Landscape Architects and Planners	Aspect Studios	International
2	Federal Government	Department of Environment and Energy - Environmental Resources Information Network	National
3	State Government	Office of Environment and Heritage	NSW
4	State Government	Greater Sydney Commission	NSW
5	State Government	Western Sydney Parklands Trust	NSW
6	State Government	Department of Planning	WA
7	Local Government	Gold Coast City Council	QLD
8	Local Government	Local Government Association of NSW	NSW
9	Local Government	City of Sydney	NSW
10	Local Government	Sutherland Shire Council	NSW
11	Local Government	Local Government Association of South Australia	SA
12	Local Government	City of Onkaparinga	SA
13	Local Government	City of Belmont	WA

14	Local Government	City of Melbourne	VIC
15	Regional Organisation	Resilient Melbourne/The Nature Conservancy	VIC

Interview questions (see Appendix A) were developed to focus on two key themes:

a) Identifying what metrics are currently being used to measure urban green space and how

b) Identifying what format of a 'tool' or resources would be most beneficial to end users

Each interview was completed by phone for 20 minutes duration and recorded digitally. Transcriptions were used to summarise findings across the above themes.

Appendix D Focus Group Methodology

Focus group participants were selected firstly from the list of interviewees and invited directly via email or phone. Existing interviewees were targeted as those who were already engaged, had existing knowledge and could provide further insights into appropriate metrics and the development of a tool. Secondly, invitations were broadcasted via interviewees own networks, those who were suggested as interviewees and were not available or unable to be interviewed within the project timeframe and through email broadcasts to the Local Government Associations in NSW.

Five half-day focus groups have been held in Sydney (28th March 2017) Melbourne (29th March 2017). Adelaide (3rd April 2017) Perth (7th April 2017) and Brisbane (18th April 2017) outlines the attendees at these focus groups.

Table D 1: **Focus Group attendees**

#	Sector	Organisation	Focus Group	Completed telephone interview?
1	State Government	Office of Environment and Heritage	Sydney	No
2	State Government	Western Sydney Parklands Trust	Sydney	Yes
3	Regional Organisation	Sydney Coastal Councils Group	Sydney	No
4	Local Government	Bayside Council	Sydney	No
5	Local Government	Southern Sydney Regional Organisation of Councils	Sydney	No
6	Local Government	Penrith City Council	Sydney	No
7	Local Government	City of Brimbank	Melbourne	No
8	Regional Organisation	Resilient Melbourne/The Nature Conservancy	Melbourne	Yes
9	Local Government	Moreland City Council	Melbourne	No
10	Local Government	Hulme City Council	Melbourne	No
11	Local Government	Hulme City Council	Melbourne	No
12	Local Government	City of Onkaparinga	Adelaide	Yes
13	Local Government	City of Marion	Adelaide	No
14	Consultant	Consultant	Adelaide	No
15	Local Government	Adelaide City Council	Adelaide	No
16	State Government	Department of Planning, Transport and Infrastructure	Adelaide	No

17	Local Government	City of Salisbury	Adelaide	No
18	State Government	Department of Environment, Water and Natural Resources	Adelaide	No
19	State Government	Department of Planning	Perth	Yes
20	Local Government	City of Belmont	Perth	Yes
21	Consultant	Consultant	Perth	No
22	Local Government	City of Fremantle	Perth	No
23	State Government	Department of Sport and Recreation	Perth	No
24	Local Government	WA Local Government Association	Perth	No
25	Local Government	City of Belmont	Perth	No
26	Consultant	Consultant	Perth	No
27	Professional Association	Australian Institute for Landscape Architects (AILA)	Brisbane	No
28	Consultant	Consultant	Brisbane	No
29	Professional Association	ParksBase	Brisbane	No
30	Consultant	Consultant	Brisbane	No

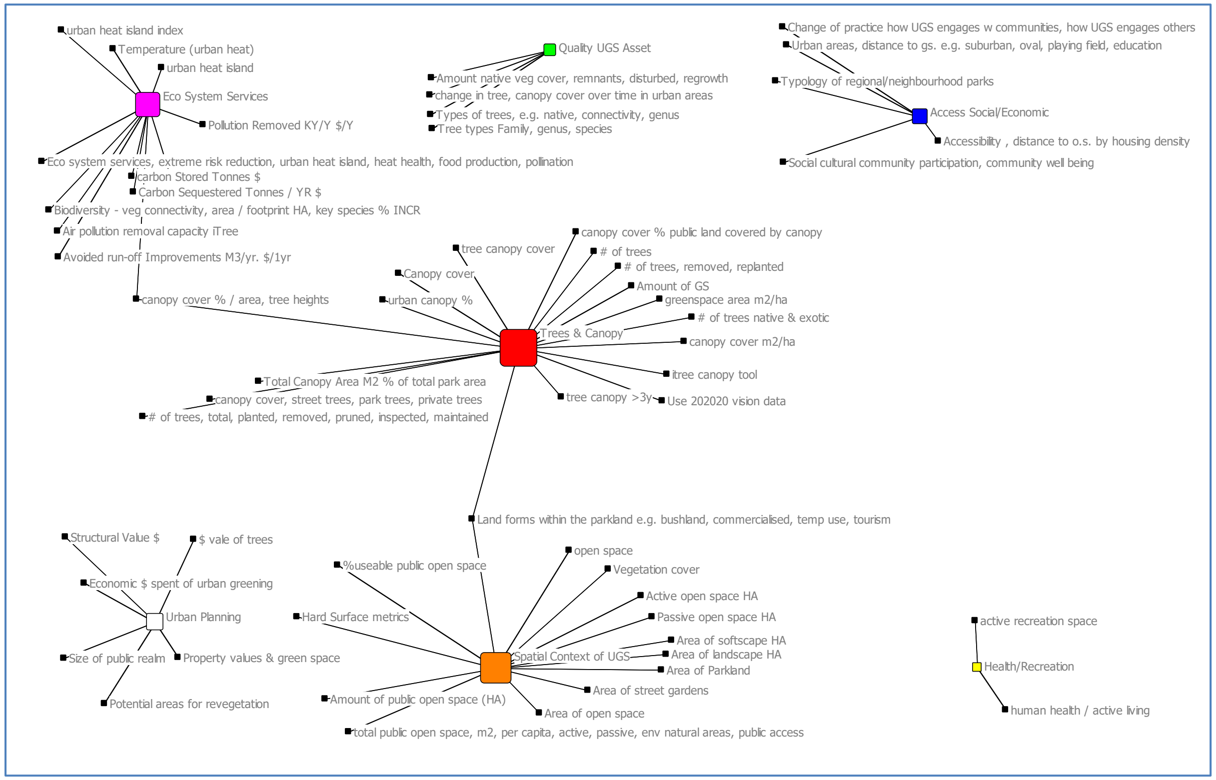
The goal of conducting focus groups was to discuss the key findings of the phone interviews with stakeholders and delve deeper into discussion on metrics and the characteristics of a potential blueprint for measuring urban green spaces in Australia. The focus groups were facilitated by ISF team members.

The following activities were undertaken through a plenary discussion in the half-day focus groups with stakeholders:

- Activity 1: **What Metrics**? This activity uncovered what metrics and indices participants currently use for measuring urban green space. Each participant listed the individual metrics and indices they currently measure as well as metrics they do not currently measure but would like to. The participants then collectively underwent an affiliation mapping exercise to group these metrics into relevant domains: for example, the metric of air pollution and temperature may fit under the domain of Eco System Services, and number of trees, or percentage of canopy grouped under Trees & Canopy, and so on.

Once participants had completed their affiliation map, the facilitators uncovered the map complied from metrics and indices from interviews, mapped against domains found from the initial literature review (see figure D: 1.The figure layout refers only to the qualitative mapping by experts. After connection to theme, placement of nodes and length of line are arbitrary).

Figure D 1: Interview metrics mapped to Literature review themes



- **Activity 2**: Application of metrics. From the long list of metrics and the grouping undertaking in Activity 1, the participants were then asked to reflect upon their experience. Based upon their professional experience, to think through 2 situations where the use of UGS metrics could improve the status quo in planning and management practices.
- **Activity 3**: a third and final group discussion explored the tool in technical terms. Participants discussed potential implementations and uses. They also responded to some preliminary questions around data sharing, custodianship policy impact.

Findings from the Focus groups can be found in Section 3.1.2 Part 2 – Focus Groups of this report.

Appendix E Focus Group Affinity Maps

The affinity maps in this section are digital representations of the analogue table-top mappings. The colour coding refers to the themes outlined in Figure 5: Interview Metrics mapped to Literature review themes. This is with the exception of the additional themes of Asset management (grey) and the "Wish" metrics (purple); these indicate metrics that participants did not yet have, but would like to implement. After each focus group the researchers mapped the findings against those reported in the interviews and literature to assist in consolidating and synthesising the findings. In some instances multiple participant groupings could be linked back to individual literature review theme, resulting in multiple groups incurring the same colour (eg. Figure E one, "Enviro Value / Bio" and "Benefits" are both pink. This links back to Figure 5: Interview Metrics mapped to Literature review themes and "Environmental Services" theme also coloured pink.

Figure E 1: Metrics affinity map and thematic grouping (NSW)

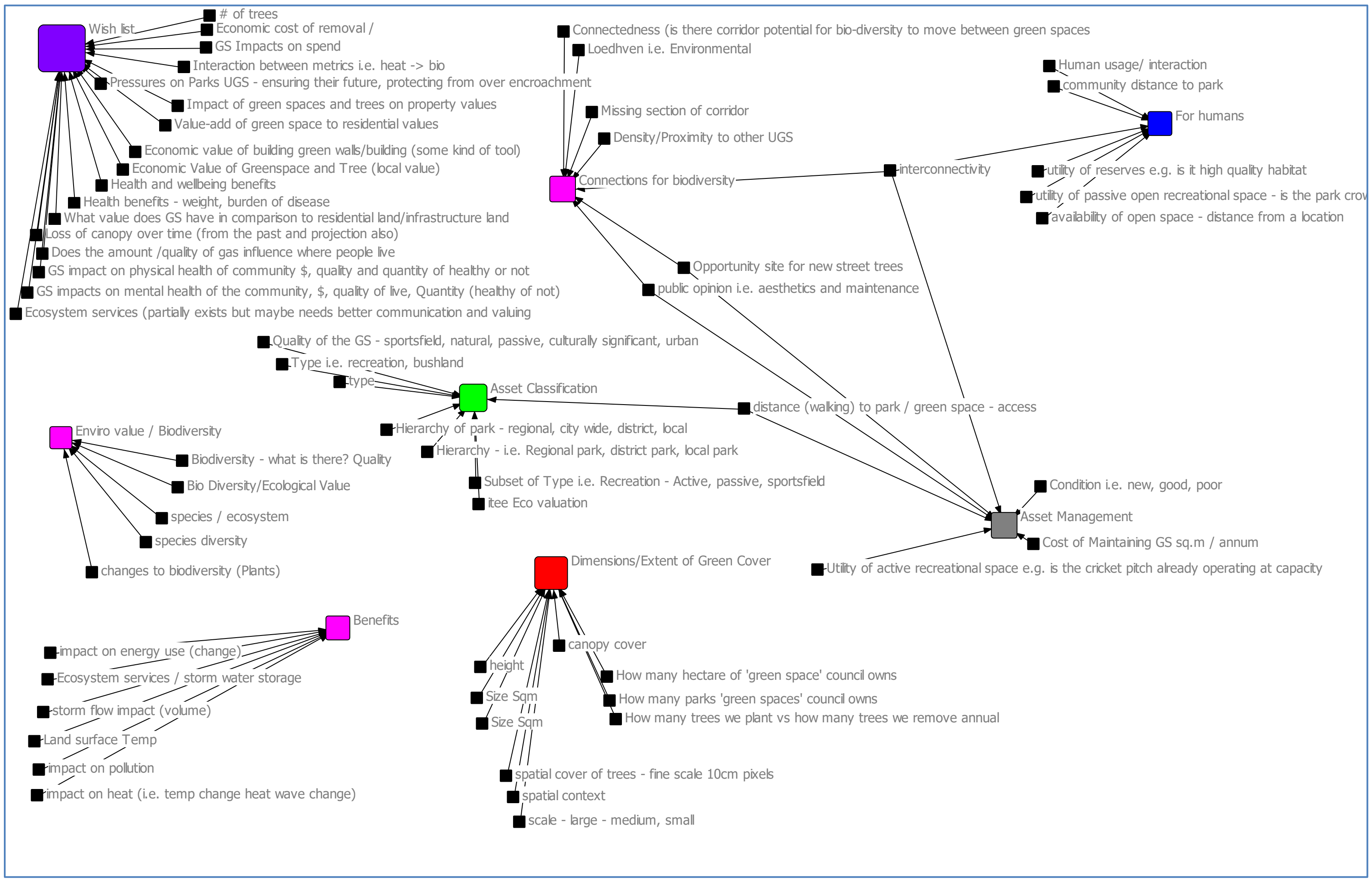


Table E 1: Legend Figure 8

	Theme	*Colour*
1	Benefits	
2	Enviro value / Biodiversity	
3	Dimensions/Extent of Green Cover	
4	Asset Classification	
5	For humans	
6	Connections for biodiversity	
7	Asset Management	
8	"Wish list" Metrics	

Table E 2: Counts of metrics by theme (NSW).

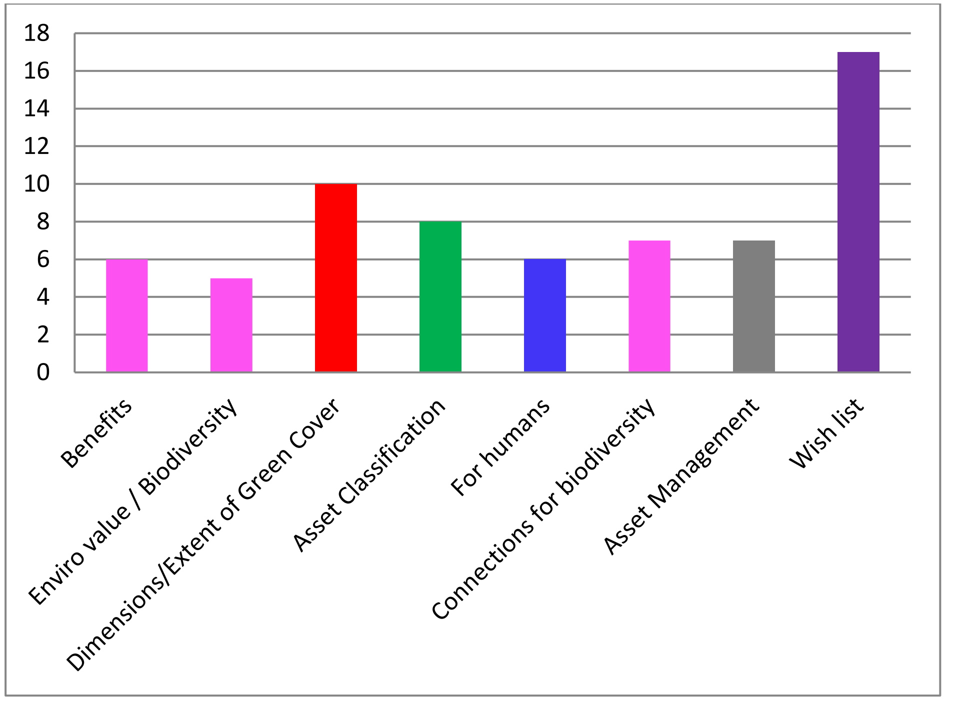


Figure E 2: Metrics affinity map and thematic grouping (VIC).

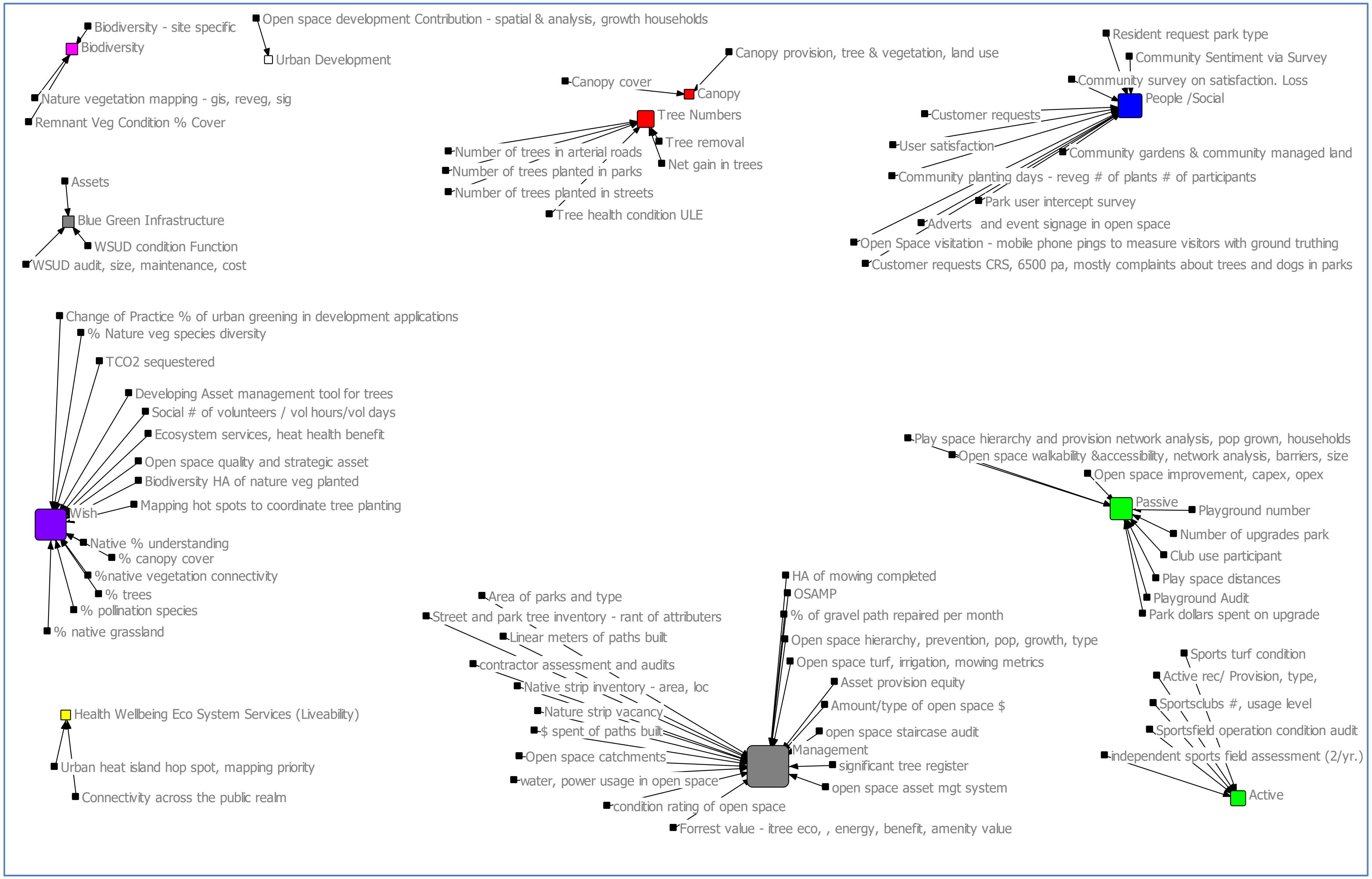


Table E 3: Legend VIC

	Theme	*Colour*
1	Urban Development	
2	Biodiversity	
3	Canopy	
4	Blue Green Infrastructure	
5	Health Wellbeing Eco System Services (Liveability)	
6	Tree Numbers	
7	People /Social	
8	Management	
9	Passive	
10	Active	
11	"Wish list" Metrics	

Figure E 3: Counts of metrics by theme (VIC)

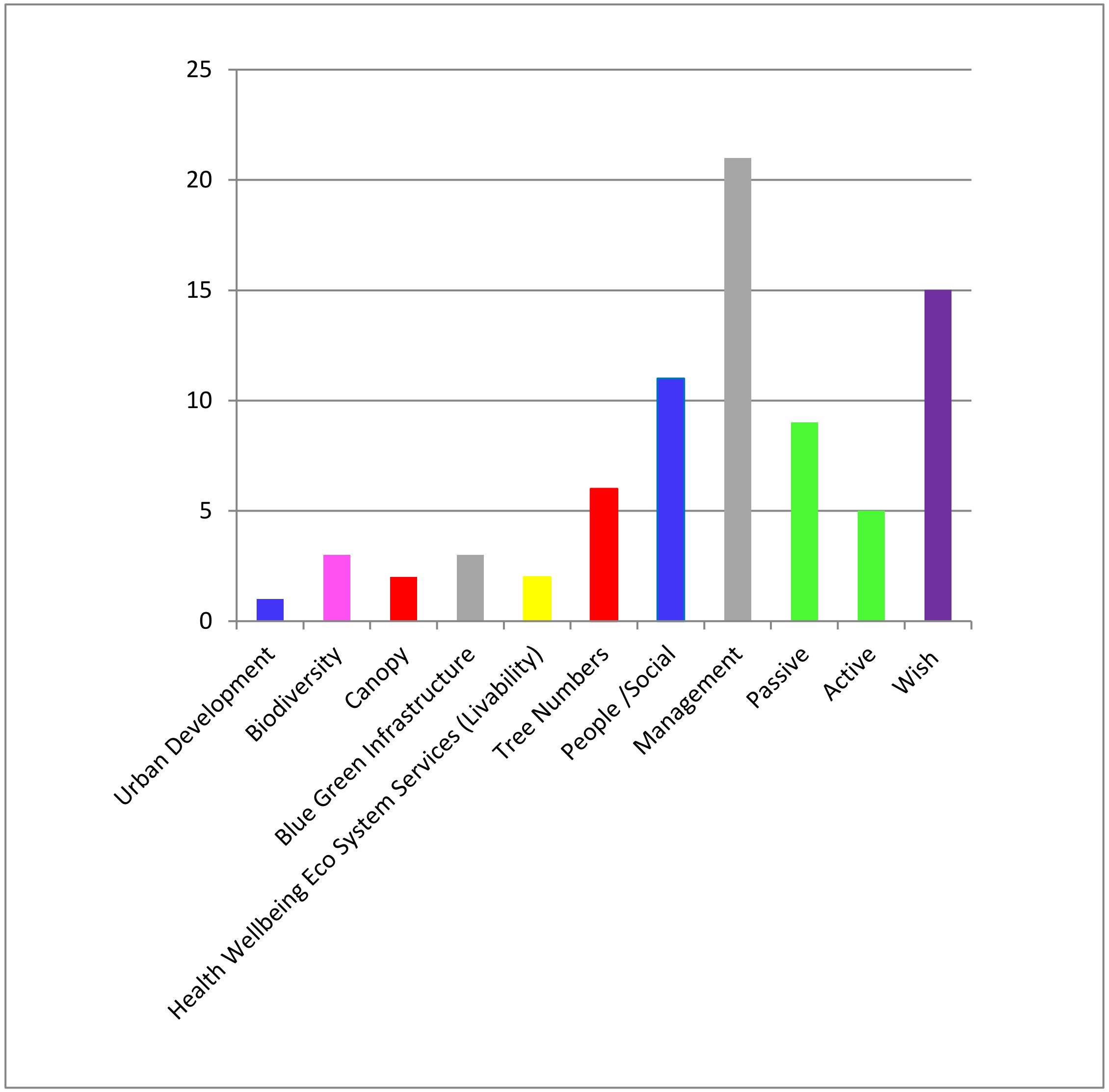


Figure E 4: Metrics affinity map (SA).

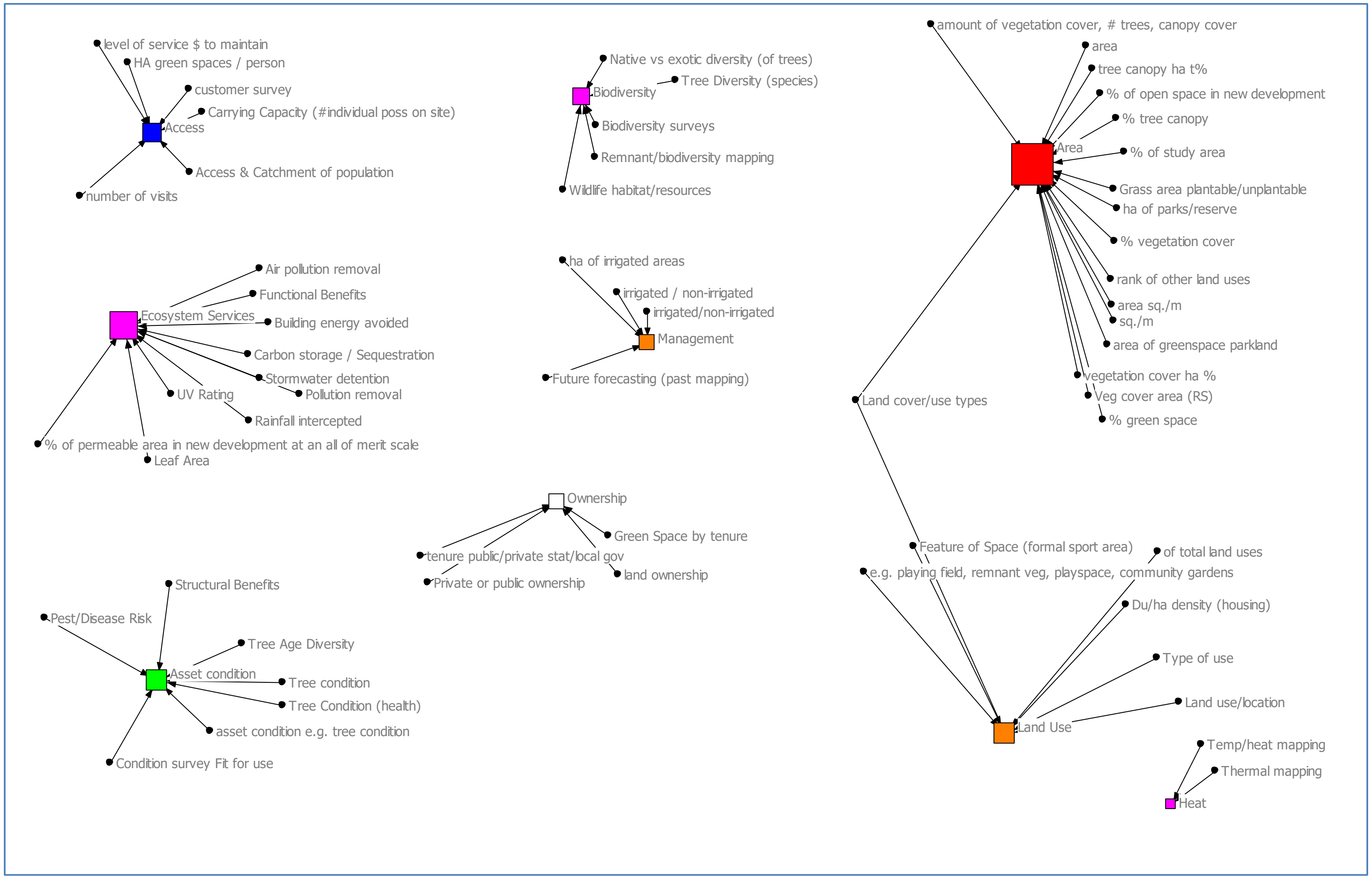


Table E 4: Legend SA

	Theme	*Colour*
1	Asset Condition	Green
2	Access	Blue
3	Ecosystem Services	Magenta
4	Ownership	White
5	Biodiversity	Magenta
6	Management	Orange
7	Land Use	Orange
8	Area	Red
9	Heat	Magenta

Figure E 5: Counts of metrics by theme (SA)

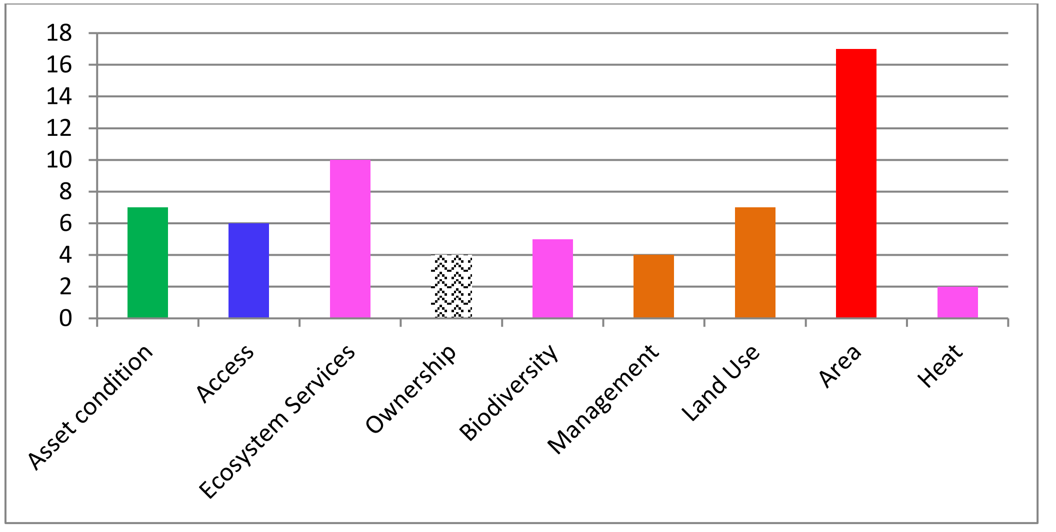


Figure E 6: Metrics affinity map (WA).

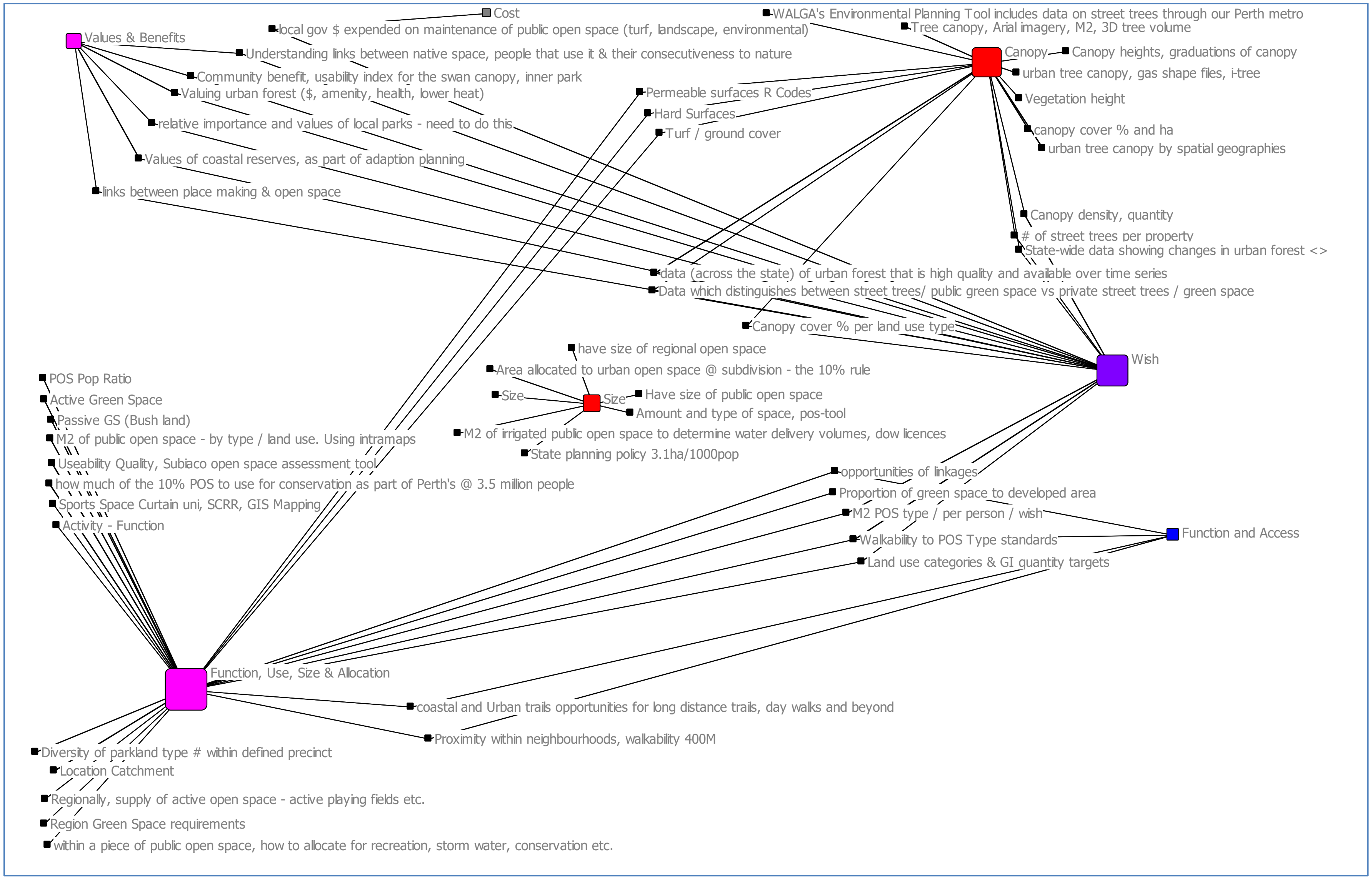


Table E 5: Legend WA

	Theme	*Colour*
1	Values and Benefits	
2	Cost	
3	Canopy	
4	Size	
5	Function and Access	
6	Wish	

Figure E 7: Counts of metrics by theme (WA)

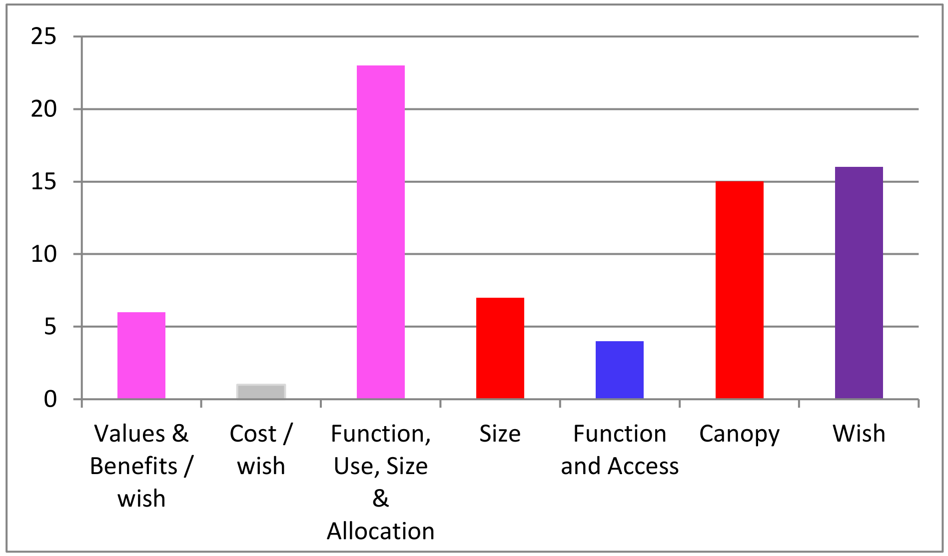


Figure E 8: Metrics affinity map (QLD)

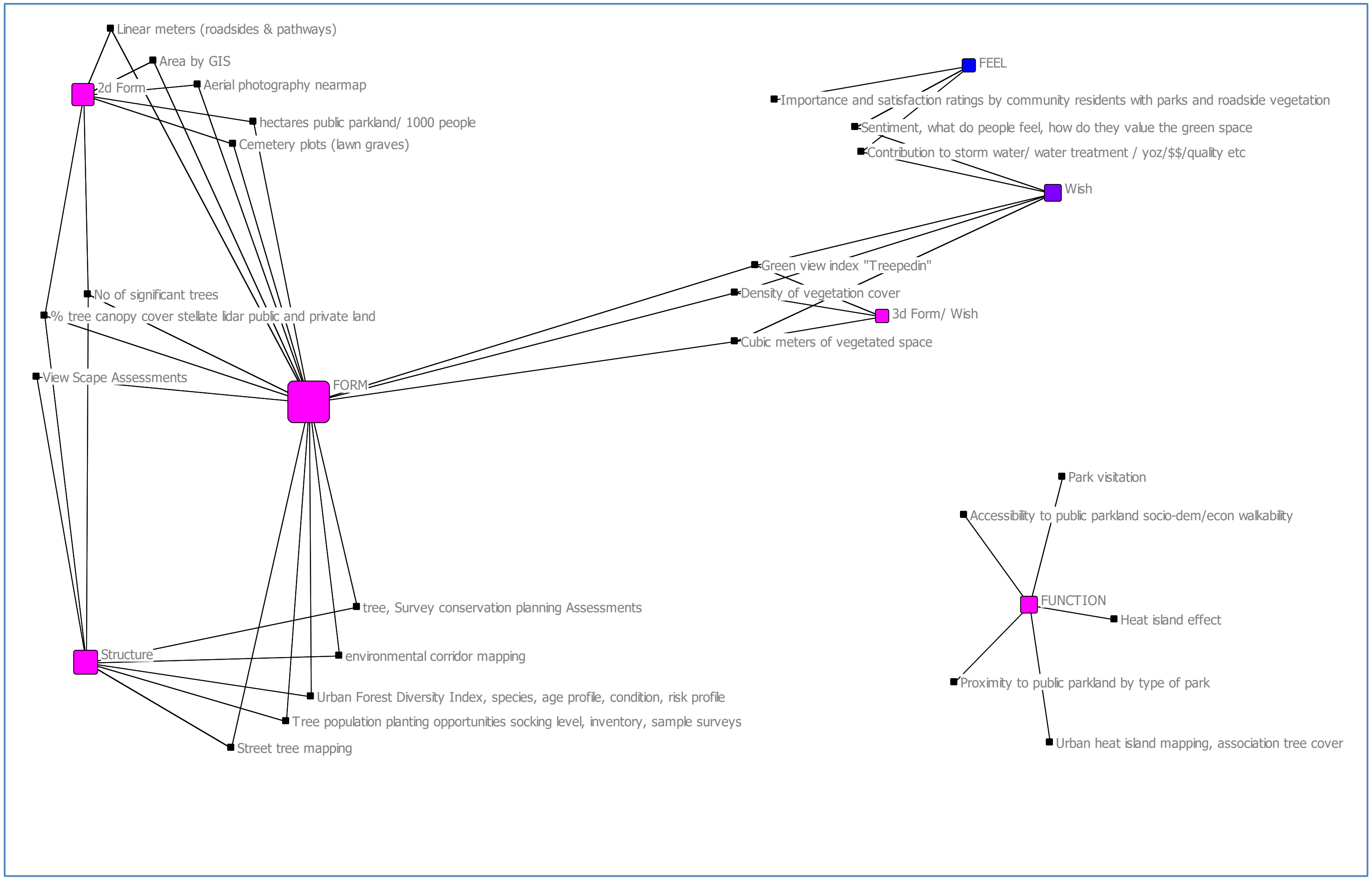
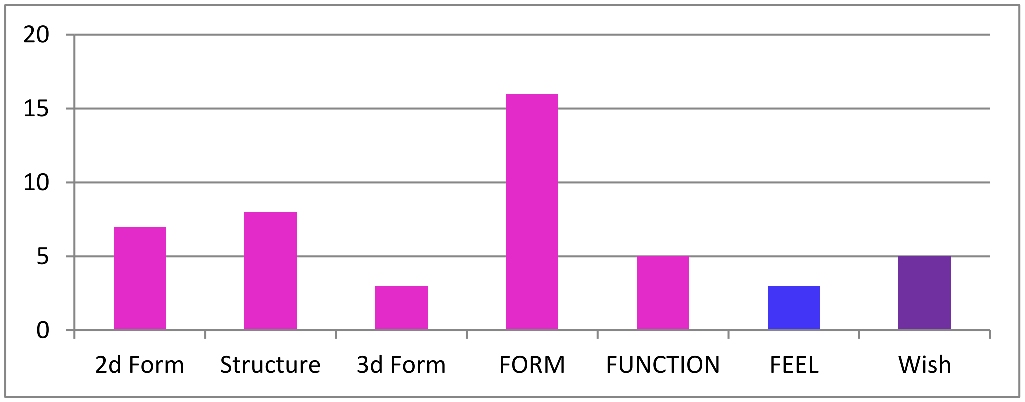


Table E 6: Legend QLD

	Theme	*Colour*
1	Form	
2	2D Form	
3	3D From	
4	Structure	
5	Function	
6	Wish	
7	Feel	

Figure E 9: Counts of metrics by theme (QLD)



Appendix F Focus Group Use Situations and Discussion

NEW SOUTH WALES

In the NSW Focus Group (held in Sydney on Tuesday 28th March 2017) two situations were workshopped: the impact of the loss of UGS on the liveability of urban areas; and adaptation to climate change.

Use situation #1 (NSW) Loss of open [green] space to other land uses – liveability of urban areas

Description of situation:

Focus Group participants chose to discuss the challenge of measuring 'value' of urban green space in the context of current public opinion, against the backdrop of the electoral cycle which incentivises policies and measures that demonstrate quick value wins. Hard cash values often overshadow softer values: for example, to a developer, value may be hard cash whereas the public value of UGS is about 'soft' cash.

This use situation ultimately pertained to the liveability of suburbs, asking the question: what is the value of open space to the community, and how can this value be best expressed? The value of UGS to the community is reflected in the public perception of UGS being there. Dollar value arising from development represents private land value only, and only in terms of market price. That is, not in terms of the services UGS performs for the benefit of the community. The loss of the green space to the community can therefore go unnoticed. The loss of UGS also means a loss of value to the community. The challenge is therefore to communicating this (loss of) value of UGS to the community.

Metrics:

The expected improvement value of the land requires additional metrics quantifying the value of UGS to the community. This would enable comparison of development scenarios, e.g. land developed for public open space; residential; roads; industrial land. Dollar value estimates of the benefits of the space to the community (public vs private value of UGS) were seen as critical.

It was seen as particularly important that open space is built into urban densification plans, so that the local communities there get an 'amenity bonus' to compensate for increasing density.

Having a baseline was also seen as important. Without a baseline it is often hard to make the case due to the time lapse of urban green space benefits (trees take time to grow). A baseline could be useful for making comparisons. What is the base value of the land? What is the improved value of the land? (e.g. when houses or roads are built). A comparative metric could address 1) the base value of the land; the value of the improved land (e.g. with houses or roads); the public value – e.g. the land could more valuable as a public park rather than under residential or commercial use or for use for infrastructure.

Spatial mapping - spatial analysis including heat maps of green spaces could be compared with other data sets, such as health data. Higher health costs, for example higher instances of mental health issues and chronic health issues could then be addressed with targeted improvements of urban green space.

Annual customer satisfaction surveys – especially longitudinal surveys - may also provide metrics. The value of parks is always in the top-five in terms of satisfaction in current customer satisfaction surveys. They could be used for the benchmarking of loss – e.g. using "intercept surveys" which ask what people do, for how long, what quality is experienced etc. Threats and risks on greenspace could be matched with - liveability maps. Currently, there is a need for examples of the success of these metrics. Rigour is important - the quality of metrics matters when making a case.

In summary, where metrics of quantity do exist and can be plugged in, this is already done. Performance metrics were identified as needed urgently to express the value of UGS to people. One participant offered that “policies are not a community service”. In one instance recalled by participants, a golf course was moved to crown land. Although golf courses are green spaces, they are not public green spaces, and thus this shift incurs an impact on publicly available open space.

Related studies and projects that may be relevant include:

- Tract Consultants; Deloitte project;
- Aecom study: System analysis of green infrastructure; quantification of the economic value of Green Infrastructure; cost-benefit analysis;
- Chicago study.

Use situation #2 (NSW) Adapting to climate change

Description of situation:

Ecosystems adapting to climate change. This brings about a need for scenarios in order to assess how areas can be ‘naturalised’, for example tree cover can serve to reduce the damage of hail storms. Monocultures are difficult, so diversification (e.g. tree species) is important.

Metrics

Current metrics are mostly at the State level, not at the local government scale. Yet, local government has a need for this type of data, e.g.

- Climate data in relation to a range of benefits;
- Tree cover;
- The impact of development on tree cover/land use and land use.

The NSW Climate change policy framework can be a push towards better practice; it adds value to green cover and this can help convince stakeholders.

At state level the development of metrics is still in its infancy (Climate Change Framework). The City of Sydney has made good progress in this space - this represents best practice. Local government is under-resourced. ROCs and coastal groups might be in a good position to develop shared capacity. The Focus Group identified a potential role for the Greater Sydney Commission (GSC) here, noting that the GSC currently has no scientists on board.

VICTORIA

For the VIC Focus Group (held in Melbourne on Tuesday 29th March 2017) the following two situations were workshopped: contested [green] infrastructure for green space; and the multifunctional use of open space, especially sports clubs.

Use situation #1 (VIC) contested [green] infrastructure for green space

Description of situation:

The ‘living’ (green) infrastructure is competing with the built infrastructure. From an asset and risk management perspective it is often challenging to argue a case for urban green space, especially trees, as the ‘services’ from urban green space are typically overshadowed by the perceived risks to, or interferences with, services from other assets, for example:

Services above-ground:

- Powerlines (high/low voltage/ transmission);
- Communication lines (ABC underground)

Several policies and regulations provide barriers and setbacks for living green infrastructure, for example the electrical line clearance regulations; guidelines and easements (LISO; power);
Services below-ground:

- Gas; sewer; water; stormwater; communications; road and footpath assets.

Traffic safety:

- Trees can be setbacks for speed, for sightlines, for parking and crossovers.
- Car parking is “sacred”

Relevant policy frameworks:

- Planning protection for Public Park and Recreation Zone (PPRZ) (open space) – these have covenants and a Committee of Management
- Growth development applications: loss of urban green space can be made explicit; this offers protection opportunities.

Metrics:

Suggested metrics required to address the challenges pertain to a variety of themes, including: active vs passive space; rate capping; land ownership and land sales (e.g. by utilities such as Melbourne Water, VIC Roads and VIC Tracks);

Metrics could be modelled after those for built assets, addressing green space asset maintenance (levels of service), provision, operation and development.

An ultimate measure would address social benefit, or value. This would help to quantify the return [on investment in urban green space] to “liveability”. One participant offered that “it is all about liveability”. Urban green space is about the public realm, UGS as a public good. Assets are council’s responsibility only, rate cappings have impacts on what can be done. If it is not beneficial for councils to manage UGS then who will manage them? Councils now be in a situation where they need to “off-load” green spaces, giving them back either to the community or to the private sector. If this is a continuing trend, who will look after the urban green space assets in the future?

Overall a metric capturing the value of trees *as infrastructure* was seen as most urgently needed. Furthermore, metrics are required to weigh up risks and benefits; risk managers are currently responding to notions of trip hazards, property damage – not community health and wellbeing. Risk/benefit analysis based on proper metrics, capturing the value of urban green space (in particular trees), has strong potential to change this situation.

Health and safety benefits also require metrics. For example, the 2009 deaths from heat stroke were higher than those for fire death. So, there may be scope to include metrics on mortality/morbidity, ambulance callouts, vulnerable persons (register); Refer to heat wave policy.

Use situation #2 (VIC): Multifunctional use of open space, especially sports clubs

Description of situation:

Strategic reframing of the public function(s) of urban green space, for example organised sports and community gardens.

Organised sports: clubs are politically active. They get funding invested. Other community groups also need meeting space. Native strips may offer scope to develop multi-functional urban green space. Low-level landscaping on nature strips would be needed in order to achieve this.

Kids' organised sports versus kids' free play – public urban green space is required for the latter activity.

Health and wellbeing – health through sports: unstructured activity is up whereas (organised) club/sports participation rates are declining. Club-specific pavilions are used occasionally.

However, more sports activity not always linearly beneficial – e.g. more alcohol consumption during droughts.

Community gardens are about sustainability and are a form of urban green space. They can be run as, or out of neighbourhood centres. Dog parks can also enhance community engagement.

There is an opportunity to include for a level of programming to get more varied open spaces.   How people use green spaces varies depending on their needs and interest, for example bicycle user groups use green spaces differently to those who interact predominantly with sports fields.

Metrics:

Ultimately, strategic reframing requires political decisions – these need to be guided by asset data and clearly defined levels of service, so that renewal requirements are clear.

Additional metrics supporting these decisions can be accommodated within the current asset management frameworks for buildings and infrastructure. Technology needs to be developed to assist in asset knowledge and management (efficient, up-to date, analytical capacity; open source data). This requires research in local government; green infrastructure.

There is also a need for better technology on the ground. Some participants had been involved with development of UGS applications. However, sometimes employees had to bring their own device in order to utilize these applications due to the low quality of equipment provided to staff (e.g. effective live devices, need for smart phones (or similar) to be provided to utilize existing technologies)

Related studies/tools:

- Brimbank uses tree tool every three years;
- RMIT Brimbank GIS tool
- VIC Roads Yardstick benchmarking tool
- Louisville, Kentucky USA; health asthma planting trees improves health.

SOUTH AUSTRALIA

For the SA Focus Group (held in Adelaide Monday 3rd April 2017) the following two situations were workshopped: Urban Infill – private vs public space; and community health and urban green space

Use situation #1 (SA): Urban Infill – Private VS Public Space

Description of situation:

There is pressure on public open space as more public open space is being bought and used by private developers at a variety of scales.

Metrics:

There was a discussion around the quality of private spaces vs the quality of the development.

Private land versus community benefit - home owners may take down individual trees on properties (for example an individual tree, or as larger estates are transformed into two or three smaller subdivisions), there is the notion that is it only one tree, here and there. However, these accumulate quickly and this group again mentioned the effect of “Death by a thousand cuts” as collectively the tree canopy thins, and diminishes, and negative impacts grow. There may be benefit for the individual home owner as they have a greater fiscal return on their investment by subdividing the property or having a build with a larger footprint, however the neighbourhood suffers the loss of yet another tree.

Finally, there was a long discussion regarding the conflict between local and state targets – on one hand there is a density target and a green target. However there is no way to reasonably and robustly bring these metrics to convergence.

Use situation #2 (SA): Community Health and Urban Green Space

Description of situation:

Although currently there are not many metrics being used to bring together the health benefits of urban green space, there is an inherent understanding of this linkage.

Metrics:

Access to urban green spaces brings benefits to health and wellbeing. There is already thermal mapping work being done. Ecosystem services do contribute to a better quality of life.

Urban Green Spaces and amenity to such spaces encourage active and healthy lifestyles thus healthy communities.

WESTERN AUSTRALIA

For the WA Focus Group (held in Perth on Friday 7th April 2017) the following two situations were workshopped: metrics that explore urban green spaces with joint ownership and Ecosystem Services vs Risk

Use situation #1 (WA) – metrics that explore urban green spaces with joint ownership

Rather than discussing a particular case in point, during the first situational exercise in WA, participants discussed particular metrics that may assist assessing urban green space owned by both public and private landholders. In this discussion, participants developed a working “metrics tree” as seen below:

- 1.1 Capturing Tree Canopy cover
- 1.2 Monitoring Tree Canopy Cover
- 2. Understand open space needs for future
    - 2.1 GIS
    - 2.2 Scales of Development & Tree loss
    - 2.3 Map what SOP/Space is there – what will be required
    - 2.4 Modelling for population growth
- 3. What’s happening to POS – what is changing over time?
- 4. Opportunity Cost Metric

Understand values and how to turn these values into a metric.

Use situation #2 (WA) Ecosystem Services vs Risk

Description of situation:

Participants moved to a more specific issue in the second use situation, describing the tensions between ecosystem services and the perceived risks of green spaces. It was discussed that these perspectives were due to individuals' values and education. However, information and facts can change points of view and indeed the potential "value" of a green asset. It was thought that it was important to express to publics why green infrastructure is essential.

In WA, there is a Guided Development Scheme which addresses the POS allocation, as well as resource allocation (i.e. water). There are ways to learn from historical planning examples. Further it would be useful for an index of public open space provision at the socio-economic scale.

For example, is there a liveability index? What metrics can demonstrate quality and affordability for residents / affordable housing, and during development, ensure that there is access to urban green spaces at that point? It would be useful to know that the dollar per square meterage of house vs the dollar per square meter of green space in relation to the return value provided.

Finally, the discussion turned to the need for getting the right tree in the right public open space, or green space.

Again, this group mentioned the difficulty of population growth while maintaining urban forest. The private and public land tensions as private landowners are legally within their rights to remove trees from properties of a certain size. This creates a 'death by 1000 cuts' scenario.

Further, there was mention of Fear, Fall, Fire: the fear of trees from an evolutionary psychology perspective, fear of falling trees, due to the media coverage of trees falling on houses or cars during storms, and bushfire.

QUEENSLAND

For the QLD Focus Group (held in Brisbane Tuesday 18th April 2017) the following two situations were workshopped: Municipality tree planting and changing the message around asset management.

Use Situation #1 (QLD): Municipality tree planting

Description of situation:

Within Queensland there was offered an example of municipalities planting trees. It is known that there is a cooling effect of tree cover in urban areas. Due to the cost and effort of tree planting, it was important to first prioritise the location – where would the trees go, and how would it fit in conjunction with existing infrastructure, (e.g., cycle paths, walkways to transport, buses/trains etc). This in turn had positive flow on effects to the people using these spaces on a regular basis.

In order to find these "shade hungry" areas, urban heat island maps were used as well as tree cover measures. This was overlayed upon areas of the highest use. This was useful; however the group discussed additional metrics or methodologies that may have been useful if available. This activity was performed in partnership with active transport, who offered a financial contribution to the project, as well as in partnership with community planting. This ensured that the community came along with the process.

The conversation turned to measures of demand, use and sentiment, as demand validates supply, rather than supplying trees for "supply sake". There was a desire to apply fine grain design to a larger scale. And also questions around how to manage these projects long term. There was a desire to be able to measure the life cost of an asset, as this may affect the decision making process.

Finally there were queries around who decides on the purpose for a design, and how to appropriately layer metrics. This may help ensure that what is needed and what is wanted in an area may be better assessed.

Metrics:

Approaches and associated metrics discussed by this focus group's participants included:

- Urban heat island mapping;
- Tree cover measures;
- Overlay areas of highest, most important use;

Partnerships/synergies could be established with active transport, offering financial contributions to projects (e.g. partnership with community planting).

Innovative metrics could address demand (use and sentiment). Demand validates supply and avoids supplying green space for supply's sake.

Participants finally pondered a series of questions:

- How do we apply fine grain design to larger scales?
  What is management longer term?
- How does this affect decision making processes?
  *What is the life cost of the asset?
- Who decides on the purpose for a design?
  - layers of metrics
- Values versus value, wants versus needs.

Use Situation #2 (QLD) Changing the message around asset management

Description of situation:

This discussion moved to the individual and how changes to urban green spaces are communicated to the community. How is value currently being communicated, and how can we better communicate the science as well as the feeling. Is it possible to measure and communicate demand at the individual level? There was a consensus that there was a gap in measurement as there is a need to articulate the benefits to an individual and the potential health and wellness benefits.

There was further discussion about the size and scale of the data (e.g., overlaying health data upon urban green data), who would be responsible for matching up the data and overlaying it so that it would be meaningful. Further, what would be the best metrics to use to ensure individuals were invested in urban green spaces (e.g. having shade on your house would lower electricity bills).

In order to fund this type of data analytics, there is a need for investment. There is the potential for government funding, however governments often have varying and sometimes conflicting priorities. Perhaps there could be private investment (e.g., health insurance). However first, there needs to be a demand for this type of work. There needs to be authentic public participation to understand the demand for urban green spaces.

Metrics:

A gap in current measurement is the benefits to an individual, for example flow-on effects to health and wellbeing

- How do we match up data?
- Who overlays the data?
- What data metrics mean to people (e.g. electricity bills?)
- How do we encourage investment?
    - Governments have a different priority?
      Private sector is looking for a return on investment (e.g. reduced health insurance payouts)
- Demand: need authentic public participation to understand demand.

Appendix G Metrics from Literature

The following indicators and (where relevant) sub indicators are listed alongside the relevant source literature.

Indicator	Sub indicator	Source
Access	Number of access points	Gidlow et al., 2012
Access	Pedestrian crossings	Gidlow et al., 2012
Access	Number of pathways	Gidlow et al., 2012
Access	Quality of pathways	Gidlow et al., 2012
Activities	Activity space: tennis	Edwards et al., 2013
Activities	Activity space: soccer	Edwards et al., 2013
Activities	Activity space: football	Edwards et al., 2013
Activities	Activity space: netball/basketball	Edwards et al., 2013
Activities	Activity space: cricket	Edwards et al., 2013
Activities	Activity space: fitness circuit	Edwards et al., 2013
Activities	Activity space: hockey	Edwards et al., 2013
Activities	Activity space: athletics	Edwards et al., 2013
Activities	Activity space: rugby	Edwards et al., 2013
Activities	Activity space: skateboarding	Edwards et al., 2013
Activities	Activity space: children's playground	Edwards et al., 2013
Activities	Activity space: other	Edwards et al., 2013
Activities	Activity space: passive only	Edwards et al., 2013
Air quality	Area of forest	Alam et al, 2016
Air quality	High traffic street within 1km radius	Alam et al, 2016
Air quality	Low traffic street within 1km radius	Alam et al, 2016
Air quality	Traffic loads	Alam et al, 2016
Air quality improvement		Barron et al, 2016
Amenities	Provision of seating	Gidlow et al., 2012
Amenities	Provision of litter bins	Gidlow et al., 2012
Amenities	Provision of lighting	Gidlow et al.,

		2012
Amenities	BBQ facilities	Edwards et al., 2013
Amenities	Seating	Edwards et al., 2013
Amenities	Public access toilets	Edwards et al., 2013
Amenities	Public art	Edwards et al., 2013
Amenities	Car parking facilities	Edwards et al., 2013
Amenities	Lighting: around buildings and equipment	Edwards et al., 2013
Amenities	Lighting: along paths	Edwards et al., 2013
Available growing space		Barron et al, 2016
Canopy cover		Barron et al, 2016
Changes in green space	Recent changes in the total area of green spaces in the last 10 years	Baycan-Levent et al., 2009
Culture and history	Relics of traditional landscapes	Van Herzele & Wiedemann, 2003
Culture and history	Cultivated parks	Van Herzele & Wiedemann, 2003
Culture and history	Old parks	Van Herzele & Wiedemann, 2003
Distance metric	Green space centroid	Higgs et al., 2012
Distance metric	Nearest boundary point	Higgs et al., 2012
Distance metric	Nearest access point	Higgs et al., 2012
Distribution	Diversity index	He et al., 2016
Distribution	Evenness index	He et al., 2016
Distribution	Dominance index	He et al., 2016
Dogs	Dogs allowed	Edwards et al., 2013
Dogs	Perimeter of POS fenced	Edwards et al., 2013
Ecological	Regulation of solar irradiation	Pakzad & Osmond, 2016
Ecological	Lowering air temperature through evapotranspiration	Pakzad & Osmond, 2016
Ecological	Wind breaking	Pakzad & Osmond, 2016
Ecological	Air quality improvement	Pakzad & Osmond, 2016
Ecological	Carbon emissions	Pakzad & Osmond, 2016
Ecological	Reduced building energy use for heating and cooling	Pakzad & Osmond, 2016

Ecological	Hydrological regulation	Pakzad & Osmond, 2016
Ecological	Improved soil quality and erosion prevention	Pakzad & Osmond, 2016
Ecological	Waste decomposition and nutrient cycling	Pakzad & Osmond, 2016
Ecological	Noise level attenuation	Pakzad & Osmond, 2016
Ecological	Biodiversity-protection and enhancement	Pakzad & Osmond, 2016
Ecological services composite	Composite indicator of the above	Alam et al, 2016
Economic	Increased property values	Pakzad & Osmond, 2016
Economic	Greater local economic activity	Pakzad & Osmond, 2016
Economic	Healthcare cost savings	Pakzad & Osmond, 2016
Economic	Economic benefits of provision services	Pakzad & Osmond, 2016
Economic	Value of avoided CO2 emissions and carbon sequestration	Pakzad & Osmond, 2016
Economic	Value of avoided energy consumption	Pakzad & Osmond, 2016
Economic	Value of air pollutant removal/avoidance	Pakzad & Osmond, 2016
Economic	Value of avoided grey infrastructure design	Pakzad & Osmond, 2016
Economic	Value of reduced flood damage	Pakzad & Osmond, 2016
Economic	Reducing cost of using private care by increased walking and cycling	Pakzad & Osmond, 2016
Effective green equivalent	Area of green space	Yao et al, 2014
Effective green equivalent	Quality of green space	Yao et al, 2014
Effective green equivalent	Accessibility of green space	Yao et al, 2014
Energy conservation		Barron et al, 2016
Environmental quality	Air temperature	Cohen et al, 2014
Environmental quality	Relative humidity	Cohen et al, 2014
Environmental quality	Wind direction	Cohen et al, 2014
Environmental quality	Wind velocity	Cohen et al, 2014
Environmental quality	Global radiation	Cohen et al, 2014
Environmental quality	Net radiation	Cohen et al, 2014
Environmental quality	Carbon monoxide	Cohen et al, 2014
Environmental quality	Respiratory particles	Cohen et al, 2014
Environmental quality	Ozone	Cohen et al, 2014
Environmental quality	Noise	Cohen et al, 2014
Environmental quality	POS on beach/river foreshore	Edwards et al.,

		2013
Environmental quality	Water feature: lake	Edwards et al., 2013
Environmental quality	Water feature: pond	Edwards et al., 2013
Environmental quality	Water feature: fountain	Edwards et al., 2013
Environmental quality	Water feature: stream	Edwards et al., 2013
Environmental quality	Water feature: wetlands	Edwards et al., 2013
Environmental quality	Other features: wildlife	Edwards et al., 2013
Environmental quality	Other feature: garden	Edwards et al., 2013
Environmental quality	Number of trees present	Edwards et al., 2013
Environmental quality	Trees placed: perimeter all	Edwards et al., 2013
Environmental quality	Trees placed: perimeter some	Edwards et al., 2013
Environmental quality	Trees placed: along paths	Edwards et al., 2013
Environmental quality	Trees placed: random	Edwards et al., 2013
Environmental quality	Walking paths within or around POS	Edwards et al., 2013
Environmental quality	Shared path within or around POS	Edwards et al., 2013
Environmental quality	Shade along path	Edwards et al., 2013
Environmental quality	Playground equipment shaded	Edwards et al., 2013
Environmental quality	Playground equipment fenced	Edwards et al., 2013
Environmental quality	Graffiti and vandalism	Edwards et al., 2013
Facilities	Degree of bio-physical access	Van Herzele & Wiedemann, 2003
Facilities	Supply of facilities	Van Herzele & Wiedemann, 2003
Financing of urban green spaces	Changes in the budget for greenery in the last two years	Baycan-Levent et al., 2009
Food and wood production	Product of the number of fruit trees and their potential amount of fruit production	Neuenschwander et al., 2014
Food and wood production	Sum of agricultural areas	Neuenschwander et al., 2014
GHG sequestration and storage		Barron et al, 2016
Habitat	Area of forest	Alam et al, 2016
Habitat	Threat density within 1km radius	Alam et al, 2016

Habitat	Fragmentation	Alam et al, 2016
Habitat	Protection status	Alam et al, 2016
Habitat	Isolation/connectivity	Alam et al, 2016
Habitat for species	Number of trees	Neuenschwander et al., 2014
Habitat for species	Number of coniferous trees	Neuenschwander et al., 2014
Habitat for species	Number of broadleaf trees	Neuenschwander et al., 2014
Habitat for species	Ratio of coniferous and deciduous plants	Neuenschwander et al., 2014
Habitat for species	Sum of potential habitat areas	Neuenschwander et al., 2014
Habitat provision		Barron et al, 2016
Health indicators	Improving bio-physical well-being	Pakzad & Osmond, 2016
Health indicators	Improving social well-being	Pakzad & Osmond, 2016
Health indicators	Improving mental well-being	Pakzad & Osmond, 2016
Incivilities	Extent of litter	Gidlow et al., 2012
Incivilities	Extent of alcohol debris/drug paraphernalia	Gidlow et al., 2012
Incivilities	Graffiti and vandalism	Gidlow et al., 2012
Indicators with 500m	Vegetation %	Apparicio et al., 2016
Indicators within 250m	Vegetation %	Apparicio et al., 2016
Indicators within the block	Vegetation %	Apparicio et al., 2016
Landscape aesthetics	Shape index	Frank et al., 2013
Landscape aesthetics	Diversity Index	Frank et al., 2013
Landscape aesthetics	Patch density	Frank et al., 2013
Landscape ecological metrics	Richness	Xu et al., 2016
Landscape ecological metrics	Accessibility	Xu et al., 2016
Landscape ecological metrics	Distribution	Xu et al., 2016
Landscape ecological metrics	Shape configuration	Xu et al., 2016
Level of performance	Success level of urban green space policy in light of the objectives of a city from the representatives' own evaluation perspective	Baycan-Levent et al., 2009
Microclimate regulation and air purification	Number of trees	Neuenschwander et al., 2014
Microclimate regulation and air purification	Sum of vegetated area	Neuenschwander et al., 2014
Natural features	Provision of grass	Gidlow et al., 2012

Natural features	Provision of trees/shrubs/plants	Gidlow et al., 2012
Natural features	Provision of flower beds	Gidlow et al., 2012
Natural features	Water features	Gidlow et al., 2012
Nature	Natural green spaces	Van Herzele & Wiedemann, 2003
Nature	Dense pattern of small landscape elements	Van Herzele & Wiedemann, 2003
Nature	Natural elements/wild places	Van Herzele & Wiedemann, 2003
Neighbourhood health	Normalised difference vegetation index (NDVI)	Alamenza et al., 2012
Neighbourhood health	Non-relevant socioeconomic indicators	Alamenza et al., 2012
Odour mitigation	Area of forest	Alam et al, 2016
Odour mitigation	Area of odour source	Alam et al, 2016
Odour mitigation	Distance from forest	Alam et al, 2016
Of all core nature areas, the proportion with several ecological connections		Saareke & Runne, 2016
Of the forest area, the proportion of border zones of forest areas		Saareke & Runne, 2016
ParkIndex	Number of parks	Kaczynski et al, 2016
ParkIndex	Distance to closest park	Kaczynski et al, 2016
ParkIndex	Total park area	Kaczynski et al, 2016
ParkIndex	Average park quality index	Kaczynski et al, 2016
Bio-physical access to nature		Barron et al, 2016
Place attachment and community cohesion	Size of individual green space	Neuenschwander et al., 2014
Place attachment and community cohesion	Average size of public green spaces	Neuenschwander et al., 2014
Planning of green spaces	Importance of green spaces to the city compared to other functions	Baycan-Levent et al., 2009
Planning of green spaces	Existence of general goals and strategies for the planning of urban green	Baycan-Levent et al., 2009
Planning of green spaces	Existence of special planning instruments for urban green spaces	Baycan-Levent et al., 2009
Planning of green spaces	Experience with citizens participation	Baycan-Levent et al., 2009
Public Open Space (POS) access	Road network distance from SA1 population weighted centroid to nearest POS border	Villanueva et al., 2015
Public Open Space (POS) access	95% dwellings have access to a local POS (<400m)	Villanueva et al., 2015
Public Open Space (POS)	95% dwellings have access to a small neighbourhood POS (<400m)	Villanueva et al.,

access		2015
Public Open Space (POS) access	95% dwellings have access to a medium neighbourhood park (<400m)	Villanueva et al., 2015
Public Open Space (POS) access	95% dwellings have access to a large neighbourhood park (<800m)	Villanueva et al., 2015
Public Open Space (POS) access	95% dwellings have access to a district park (<800m)	Villanueva et al., 2015
Public Open Space (POS) access	95% dwellings have access to a regional park (5km to 10km)	Villanueva et al., 2015
Public Open Space (POS) quality	A quality score based on attributes and amenities	Villanueva et al., 2015
Public Open Space (POS) quality quantity	% POS area within SA1 (Statistical Area level 1. Part of the ABS geographical standard for a spatial unit of analysis)	Villanueva et al., 2015
Public Open Space (POS) quality quantity	% POS area of subdivisible SA1 land area	Villanueva et al., 2015
Public Open Space (POS) quality quantity	# of POS available within SA1	Villanueva et al., 2015
Public Open Space (POS) quality quantity	# POS by size/type within SA1	Villanueva et al., 2015
Property value benefits		Barron et al, 2016
Proportion of large uniform forest areas		Saareke & Runne, 2016
Proportion of those forest areas with core areas of over 200ha		Saareke & Runne, 2016
Quality	Mean size of green space	de la Barrera et al, 2016
Quality	Shape index of green space	de la Barrera et al, 2016
Quality	Vegetation cover	de la Barrera et al, 2016
Quality	Vegetation cover per inhabitant	de la Barrera et al, 2016
Quality	Proportion of natural vegetation area	He et al., 2016
Quality	Proportion of evergreen plants	He et al., 2016
Quality	Tree species richness	He et al., 2016
Quality	Level of vegetation succession	He et al., 2016
Quality	Bird species richness	He et al., 2016
Quality	Proportion of water area	He et al., 2016
Quality	Presence of lake/river/fountain	He et al., 2016
Quality	Presence of hill/slope	He et al., 2016
Quality	Number of elements per area	He et al., 2016
Quality	Presence of jogging path/playground	He et al., 2016
Quality	Presence of amenities	He et al., 2016
Quality	Proportion of vegetation in different stages of abandonment	He et al., 2016
Quality	Density of weed	He et al., 2016
Quality	Presence of waste	He et al., 2016
Quality	Condition of facilities	He et al., 2016

Quality	Management frequency	He et al., 2016
Quality	Number of crimes per area	He et al., 2016
Quantity	Green space per inhabitant	de la Barrera et al, 2016
Quantity	Green space per built area	de la Barrera et al, 2016
Quantity	Green space per impervious cover	de la Barrera et al, 2016
Quantity	Green space per bare soils	de la Barrera et al, 2016
Quantity	Green space per vegetation cover	de la Barrera et al, 2016
Quantity	UGS area	He et al., 2016
Quantity	Green coverage rate	He et al., 2016
Quantity	Water area	He et al., 2016
Quantity	Number of UGS elements	He et al., 2016
Quantity	Number of facilities	He et al., 2016
Quantity and availability of urban green spaces	Proportion of green spaces with respect to total area	Baycan-Levent et al., 2009
Quantity and availability of urban green spaces	Proportion of green spaces per 1,000 inhabitants	Baycan-Levent et al., 2009
Quantity and availability of urban green spaces	Existence of regional green space system	Baycan-Levent et al., 2009
Quietness	Proximity to major infrastructure	Van Herzele & Wiedemann, 2003
Quietness	Statistical noise levels	Van Herzele & Wiedemann, 2003
Recreation	Sum of the areas of public and private green spaces	Neuenschwander et al., 2014
Recreation facilities	Number of pieces of equipment	Gidlow et al., 2012
Recreation facilities	Quality of equipment	Gidlow et al., 2012
Recreation facilities	Amount of open space	Gidlow et al., 2012
Recreation facilities	Quality of open space	Gidlow et al., 2012
Socio-cultural	Food production	Pakzad & Osmond, 2016
Socio-cultural	Opportunities for recreation, tourism and social interaction	Pakzad & Osmond, 2016
Socio-cultural	Improving pedestrian ways and their connectivity	Pakzad & Osmond, 2016
Socio-cultural	Improving accessibility	Pakzad & Osmond, 2016
Socio-cultural	Provision of outdoor sites for education and research	Pakzad & Osmond, 2016
Socio-cultural	Reduction of crimes and fear of crime	Pakzad & Osmond, 2016

Socio-cultural	Attachment to place and sense of belonging	Pakzad & Osmond, 2016
Socio-cultural	Enhancing attractiveness of cities	Pakzad & Osmond, 2016
Space	Visual variation	Van Herzele & Wiedemann, 2003
Space	Attractive visual context	Van Herzele & Wiedemann, 2003
Space	Closeness	Van Herzele & Wiedemann, 2003
Spatial distribution and accessibility	Aggregation index of green space	de la Barrera et al, 2016
Spatial distribution and accessibility	Share of blocks served by green space	de la Barrera et al, 2016
Spatial distribution and accessibility	Share of population served by green space	de la Barrera et al, 2016
Stormwater control		Barron et al, 2016
The proportion of forest areas large that 5ha to all green and forested areas inside the densely populated area		Saareke & Runne, 2016
The proportion of groundwater areas classified as risky		Saareke & Runne, 2016
The proportion of inhabitants living no more than 300m from an area suitable for recreation inside the densely built area		Saareke & Runne, 2016
The proportion of land areas suitable for recreation inside the densely build area and outside densely built areas		Saareke & Runne, 2016
The proportion of paved land (non-permeable surfaces) of the total area of groundwater areas		Saareke & Runne, 2016
The ratio of inhabitants to the total area of areas suitable for recreation		Saareke & Runne, 2016
Tree risk		Barron et al, 2016
Urban Green Space Indicator	Proportion of inhabitants with access to green space compared to total inhabitants	Van den Bosche et al., 2016
Urban Neighbourhood Green Index	Percentage of green in each cell	Gupta et al., 2012
Urban Neighbourhood Green Index	Proximity to green cell	Gupta et al., 2012
Urban Neighbourhood Green Index	Density of built up	Gupta et al., 2012
Urban Neighbourhood Green Index	Height of structures	Gupta et al., 2012
Urban tree diversity		Barron et al, 2016
Visual access to nature		Barron et al, 2016
Water flow regulation	Sum of unsealed areas	Neuenschwander et al., 2014
Water flow regulation	Percentage of unsealed areas	Neuenschwander et al., 2014
	Trees/shrubs %	Apparicio et al., 2016
	Population density	Apparicio et al.,

		2016
	Median age of residential buildings	Apparicio et al., 2016
	0-14 years old %	Apparicio et al., 2016
	65 years old and over %	Apparicio et al., 2016
	Visible minorities %	Apparicio et al., 2016
	Low income population	Apparicio et al., 2016
	Trees/shrub %	Apparicio et al., 2016
	Population density	Apparicio et al., 2016
	Median age of residential buildings	Apparicio et al., 2016
	Trees/shrubs %	Apparicio et al., 2016
	Population density	Apparicio et al., 2016
	Median age of residential buildings	Apparicio et al., 2016

Appendix H Metrics from Focus Groups

Location	Groupings and Metrics
NSW	Benefits
NSW	Enviro value / Biodiversity
NSW	Dimensions/Extent of Green Cover
NSW	Asset Classification
NSW	For humans
NSW	Connections for biodiversity
NSW	Asset Management
NSW	Wish list
NSW	impact on energy use (change)
NSW	storm flow impact (volume)
NSW	impact on pollution
NSW	impact on heat (i.e. temp change heat wave change)
NSW	Ecosystem services / storm water storage
NSW	Land surface Temp
NSW	species diversity
NSW	species / ecosystem
NSW	changes to biodiversity (Plants)
NSW	Bio Diversity/Ecological Value
NSW	Biodiversity - what is there? Quality
NSW	How many trees we plant vs how many trees we remove annual
NSW	height
NSW	scale - large - medium, small
NSW	spatial context
NSW	How many hectare of 'green space' council owns
NSW	Size sqm
NSW	How many parks 'green spaces' council owns
NSW	Size sqm
NSW	spatial cover of trees - fine scale 10cm pixels
NSW	canopy cover
NSW	Quality of the GS - sports field, natural, passive, culturally significant, urban
NSW	type
NSW	Hierarchy of park - regional, city wide, district, local
NSW	Hierarchy - i.e. Regional park, district park, local park
NSW	Type i.e. recreation, bushland
NSW	Subset of Type i.e. Recreation - Active, passive, sports field
NSW	i-Tree Eco valuation
NSW	distance (walking) to park / green space - access
NSW	How far are community members to parks?
NSW	availability of open space - distance from a location
NSW	utility of reserves e.g. is it high quality habitat
NSW	utility of passive open recreational space - is the park crowded
NSW	Human usage/ interaction

Location	Groupings and Metrics
NSW	interconnectivity
NSW	Density/Proximity to other UGS
NSW	Connectedness (is there corridor potential for bio-diversity to move between green spaces
NSW	Missing section of corridor
NSW	Opportunity sites for new street trees
NSW	public opinion i.e. aesthetics and maintenance
NSW	Utility of active recreational space e.g. is the cricket pitch already operating at capacity
NSW	Condition i.e. new, good, poor
NSW	Cost of Maintaining GS sqm / annum
NSW	Economic cost of removal
NSW	Health and wellbeing benefits
NSW	Ecosystem services (partially exists but maybe needs better communication and valuing
NSW	Impact of green spaces and trees on property values
NSW	Interaction between metrics i.e. heat -> bio
NSW	Health benefits - weight, burden of disease
NSW	GS Impacts on spend
NSW	GS impacts on mental health of the community, $, quality of live, Quantity (healthy of not)
NSW	Economic Value of Greenspace and Tree (local value)
NSW	Economic value of building green walls/building (some kind of tool)
NSW	Value-add of green space to residential values
NSW	What value does GS have in comparison to residential land/infrastructure land
NSW	Does the amount /quality of GS influence where people live
NSW	# of trees
NSW	GS impact on bio-physical health of community $, quality and quantity of healthy or not
NSW	Loss of canopy over time (from the past and projection also)
NSW	Pressures on Parks UGS - ensuring their future, protecting from over encroachment
VIC	Urban Development
VIC	Biodiversity
VIC	Canopy
VIC	Blue Green Infrastructure
VIC	Health Wellbeing Eco System Services (Liveability)
VIC	Tree Numbers
VIC	People /Social
VIC	Management
VIC	Passive
VIC	Active
VIC	Open space development Contribution - spatial & analysis, growth households
VIC	Biodiversity diversity - site specific
VIC	Nature vegetation mapping - GIS, Revegetation etc.
VIC	Remnant Veg Condition % Cover
VIC	Canopy cover

Location	Groupings and Metrics
VIC	Canopy provision, tree & vegetation, land use
VIC	Water Sensitive Urban Design audit, size, maintenance, cost
VIC	Assets
VIC	WSUD condition Function
VIC	Urban heat island hop spot, mapping priority
VIC	Connectivity across the public realm
VIC	Number of trees planted in streets
VIC	Number of trees planted in parks
VIC	Number of trees in arterial roads
VIC	Tree removal
VIC	Tree health condition ULE
VIC	Net gain in trees
VIC	Customer requests through Common Reporting Standard CRS, 6500 pa, mostly complaints about trees and dogs in parks
VIC	Community planting days - reveg # of plants # of participants
VIC	Open Space visitation - mobile phone pings to measure visitors with ground trothing
VIC	Park user intercept survey
VIC	User satisfaction
VIC	Customer requests
VIC	Community Sentiment via Survey
VIC	Community gardens & community managed land
VIC	Resident request park type
VIC	Advertisings and event signage in open space
VIC	Community survey on satisfaction. Loss
VIC	$ spent of paths built
VIC	Linear meters of paths built
VIC	Amount/type of open space $
VIC	Nature strip vacancy
VIC	Value – i-Tree Eco, energy, benefit, amenity value
VIC	Street and parktree inventory - rate of attributes
VIC	Active strip inventory - area, location
VIC	significant tree register
VIC	contractor assessment and audits
VIC	Open Space Asset Management Plan (OSAMP)
VIC	Asset provision equity
VIC	water, power usage in open space
VIC	condition rating of open space
VIC	% of gravel path repaired per month
VIC	open space staircase audit
VIC	open space asset management system
VIC	Open space turf, irrigation, mowing metrics
VIC	Open space catchments
VIC	Hectare of mowing completed
VIC	Area of parks and type
VIC	Open space hierarchy, prevention, pop, growth, type

Location	Groupings and Metrics
VIC	Club use participant
VIC	Playground number
VIC	Open space walkability &accessibility, network analysis, barriers, size
VIC	Playspace hierarchy and provision network analysis, population growth, households
VIC	Playspace distances
VIC	Playground Audit
VIC	Open space improvement, capex, opex
VIC	Number of upgrades park
VIC	Park dollars spent on upgrade
VIC	Sports turf condition
VIC	Sportsfield operation condition audit
VIC	independent sports field assessment (2/yr)
VIC	Active rec/ Provision, type,
VIC	Sportsclubs #, usage level
VIC	% Nature veg species diversity
VIC	% native grassland
VIC	%native vegetation connectivity
VIC	% pollination species
VIC	Ecosystem services, heat health benefit
VIC	CO_2 sequestered
VIC	Mapping hot spots to coordinate tree planting
VIC	% canopy cover
VIC	% trees
VIC	Biodiversity HA of nature veg planted
VIC	Native % understanding
VIC	Change of Practice % of urban greening in development applications
VIC	Social # of volunteers / vol hours/vol days
VIC	Developing Asset management tool for trees
VIC	Open space quality and strategic asset
SA	Asset condition
SA	Access
SA	Ecosystem Services
SA	Ownership
SA	Biodiversity
SA	Management
SA	Land Use
SA	Area
SA	Heat
SA	Condition survey Fit for use
SA	Tree Condition (health)
SA	Tree condition
SA	asset condition e.g. tree condition
SA	Tree Age Diversity
SA	Structural Benefits

Location	Groupings and Metrics
SA	Pest/Disease Risk
SA	Carrying Capacity (#individual poss on site)
SA	Hectare of green spaces per person
SA	level of service $ to maintain
SA	customer survey
SA	number of visits
SA	Access & Catchment of population
SA	Function Benefits
SA	Carbon storage / Sequestration
SA	Leaf Area
SA	UV Rating
SA	% of permeable area in new development at an all of merit scale
SA	Building energy avoided
SA	Air pollution removal
SA	Stormwater detention
SA	Rainfall intercepted
SA	Pollution removal
SA	land ownership
SA	Green Space by tenure
SA	tenure public/private stat/local gov
SA	Private or public ownership
SA	Tree Diversity (species)
SA	Wildlife habitat/resources
SA	Native vs exotic diversity (of trees)
SA	Biodiversity surveys
SA	Remnant/biodiversity mapping
SA	irrigated / non-irrigated
SA	irrigated/non-irrigated
SA	Future forecasting (past mapping)
SA	ha of irrigated areas
SA	% of total land uses
SA	e.g. playing field, remnant vegetation, playspace, community gardens
SA	Dwelling units per hectare, density (housing)
SA	Feature of Space (formal sport area)
SA	Land use/location
SA	Type of use
SA	Land cover/use types
SA	% vegetation cover
SA	tree canopy ha t%
SA	amount of vegetation cover, # trees, canopy cover
SA	vegetation cover ha %
SA	rank of other land uses
SA	Grass area plantable/unplantable
SA	% tree canopy

Location	Groupings and Metrics
SA	Veg cover area (RS)
SA	% of open space in new development
SA	% of study area
SA	ha of parks/reserve
SA	% green space
SA	area sqm
SA	Area
SA	sqm
SA	area of greenspace parkland
SA	Temp/heat mapping
SA	Thermal mapping
WA	Values & Benefits / wish
WA	Cost / wish
WA	Function, Use, Size & Allocation
WA	Size
WA	Function and Access
WA	Canopy
WA	Understanding links between active space, people that use it & their connectiveness to nature
WA	Valuing urban forest ($, amenity, health, lower heat)
WA	Community benefit, usability for the swan canopy, inner park
WA	relative importance and values of local parks - need to do this
WA	Values of coastal reserves, as part of adaption planning
WA	links between place making & open space
WA	local gov $ expended on maintenance of public open space (turf, landscape, environmental)
WA	Region Green Space requirements
WA	Active Green Space
WA	Regionally, supply of active open space - active playing fields etc
WA	Public Open Space per population ratio
WA	The Centre for Sport and Recreation Research (CSRR), GIS Mapping
WA	Passive GS (Hashish land)
WA	Would like metric for: Metres Squared of public open space per type (of POS) per person
WA	Proportion of green space to developed area
WA	Useability Quality, Subiaco open space assessment tool
WA	Land use categories & GI quantity targets
WA	Location Catchment
WA	M2 of public open space - by type / land use. Using intramaps
WA	within a piece of public open space, how to allocate for recreation, storm water, conservation etc
WA	Diversity of parkland type # within defined precinct
WA	Activity - Function
WA	how much of the 10% POS to use for conservation as part of Perth’s @ 3.5 million people
WA	Size

Location	Groupings and Metrics
WA	Have size of public open space
WA	have size of regional open space
WA	State planning policy 3.1ha/1000pop
WA	M2 of irrigated public open space to determine water delivery volumes, Department of Water (DoW) licences
WA	Amount and type of space, pos-tool University of Western Australia
WA	Area allocated to urban open space @ subdivision - the 10% rule
WA	Walkability to POS Type standards
WA	Proximity within neighbourhoods, walkability 400m
WA	opportunities of linkages
WA	coastal and Urban trails opportunities for long distance trails, day walks and beyond
WA	Turf / ground cover
WA	Permeable surfaces Residential Design Codes (R Codes)
WA	Hard Surfaces
WA	Canopy heights, graduations of canopy
WA	Vegetation height
WA	Tree canopy, aerial imagery, M2, 3D tree volume
WA	data (across the state) of urban forest that is high quality and available over time series
WA	Canopy density, quantity
WA	Data which distinguishes between street trees/ public green space vs private street trees / green space
WA	WALGA's Environmental Planning Tool includes data on street trees through our Perth metro
WA	# of street trees per property
WA	urban tree canopy, gis shape files, i-Tree
WA	canopy cover % and ha
WA	State-wide data showing changes in urban forest <>
WA	urban tree canopy by spatial geographies
WA	Canopy cover % per land use type
QLD	2d Form
QLD	Structure
QLD	3d Form/ Wish
QLD	FORM
QLD	FUNCTION
QLD	FEEL
QLD	Cemetery plots (lawn graves)
QLD	Linear meters (roadsides & pathways)
QLD	hectares public parkland/ 1000 people
QLD	Area by GIS
QLD	Aerial photography nearmap
QLD	"% tree canopy cover data from satellite, Light Detection and Ranging (LIDAR), public and private land"
QLD	No. of significant trees
QLD	environmental corridor mapping
QLD	tree, Survey conservation planning Assessments

Location	Groupings and Metrics
QLD	Street tree mapping
QLD	View Scape Assessments
QLD	Tree population planting opportunities socking level, inventory, sample surveys
QLD	Urban Forest Diversity Index, species, age profile, condition, risk profile
QLD	Cubic metres of vegetated space
QLD	Density of vegetation cover
QLD	Green view index "Treepedin"
QLD	Heat island effect
QLD	Park visitation
QLD	Urban heat island mapping, association tree cover
QLD	Proximity to public parkland by type of park
QLD	Accessibility to public parkland socio-dem/econ walkability
QLD	Contribution to storm water/ water treatment /$$/quality etc
QLD	Importance and satisfaction ratings by community residents with parks and roadside vegetation
QLD	Sentiment, what do people feel, how do they value the green space

Appendix I Annotated Bibliography

Alam, M., et al. (2016). "A framework towards a composite indicator for urban ecosystem services." Ecological Indicators **60**: 38-44.

This paper describes the development of a composite indicator to give an overview of the performance of urban ecosystem services. The motivation behind this study is the growing demand for ecosystem services indicators, and the often high cost associated with collecting data need for these indicators. The authors present a newly developed composite indicator, which is then tested on a case study of a Canadian city. Composite indicators are used often in environmental monitoring, but not as common in the context of ecosystem services. The proposed indicator is composite in that several measures have been combined into a single indicator. The strength of the composite depends both on the quality of the variables selected, and the relevance of those indicators for measuring ecosystem services. A wide selection of indicators were identified with a smaller selection normalised and aggregated into a single composite. These indicators include air quality indicators (e.g., area of forest, traffic loads); habitat (area of forest, protection status), and odour mitigation (area of odour source, distance from forest).

This paper is useful considering that bio-physical data related to urban green space can be costly or resource intensive to obtain. The claim made by the authors is that the developed composite indicator can be used in resource-scarce situations as a way to assess ecosystem service performance of urban green space. Not strictly related to the measurement of urban green space, this paper describes a method for assessing ecosystem services with a variety of indicators that could also be applied to developing an urban green space composite.

Apparicio, P., et al. (2016). "Spatial distribution of vegetation in and around city blocks on the Island of Montreal: A double environmental inequity?" Applied Geography **76**: 128-136.

This paper presents an analysis of the spatial distribution of urban vegetation in Montreal, Canada, specifically examining the links between vegetation cover and socioeconomics.

The authors group the Montreal population into four income groups, and derive six indicators of urban vegetation from satellite imagery. These indicators are vegetation percentage and trees/shrubs percentage, calculated within residential blocks, within 250m of residential blocks, and within 500m of residential blocks. Deriving indicators based on distance of vegetation to residential blocks adds a bio-physical accessibility element which is important when considering general accessibility to green space. The analysis used regression modelling to determine the effect of socioeconomic status on green cover accessibility, finding that in general, lower income residents are disadvantaged when it comes to accessing public green space.

This is a useful paper for highlighting the important relationship between green space and socioeconomics. The indicators presented in this paper can be used for analysing levels of accessibility to green space based on neighbourhood blocks.

Badiu, D. L., et al. (2016). "Is urban green space per capita a valuable target to achieve cities' sustainability goals? Romania as a case study." Ecological Indicators **70**: 53-66.

This paper explores the application of urban green space per capita as an effective indicator to measure performance of urban green space on urban sustainability goals, through statistical modelling. The primary motivation of this study is a lack of information on quantity, structure and determinants of urban green space and driving factors of green space in

Romania related to meeting and monitoring progress towards sustainability goals.

To determine if the per capita metric is sufficient for urban green space assessment, the authors analyse available data on the distribution and variability of green space across several cities in Romania to identify patterns of green space, and to assess determinants of green space. Linear regression was used to identify what factors (e.g., urban density, age of city, landscape variation, socioeconomics etc) most influenced green space. The research findings indicate that several factors influence green space in Romania, and the green space-per capita metric is not sufficient when used exclusively as an indicator of urban green space performance, as other influencing factors are ignored.

This paper is useful as it highlights that a common indicator for green space is perhaps not a sufficient indicator for urban green space performance. The paper identifies several variables that influence green space that need to be considered when planning future urban green spaces. While this paper is specific to Romanian cities, similar exploratory analyses of green space and structural/demographic/socioeconomic factors are important to conduct in determining comprehensive performance indicators for urban green space.

Barron, S., et al. (2016). "Urban forest indicators for planning and designing future forests." Forests **7**: 208-225.

This research takes a Delphi approach to develop a decision support framework with a set of key indicators for resilient urban forests by engaging with stakeholders, academics and practitioners. The primary motivation behind this research is that while sets of indicators exist for forestry and urban design, existing indicator sets do not capture the full range of benefits that come with urban forests, particularly centred on health and well-being of urban residents. An important discussion point is given on the characteristics of good indicators, which must be: relevant, credible, measurable, cost-effective, and connected to urban forestry. With these characteristics in mind, the authors evaluate potential indicators.

Indicators that were evaluated based on expert opinions were both quantitative and qualitative, and informed from the literature on urban green space literature. After weighting indicators under the Delphi method, a final set of relevant indicators were derived to best measure performance of urban forests: urban tree diversity, bio-physical access to nature, canopy cover, storm water control, habitat provision, air quality improvement, visual access to nature, available growing space, and greenhouse gas sequestration and storage.

While not providing an indicator for the measurement of urban green space directly, this paper remains useful by not only providing a set of useful indicators for measuring the performance of green space, but also as a method for selecting locally specific indicators through comprehensive stakeholder engagement.

Baycan-Levent, T., et al. (2009). "A multi-criteria evaluation of green spaces in European cities." European Urban and Regional Studies **16**(2): 193-213.

This paper presents a multi-criteria evaluation of urban green performance across 24 European cities. The article examines urban green spaces from the viewpoint of relevant green space indicators, and employs Regime Analysis - a multi-criteria analysis technique for mixed quantitative and qualitative information. The primary aim of this paper is to develop a framework for comparing green space performance across varying urban environments in Europe.

The article uses a number of quantitative and qualitative criteria and associated sub-criteria for assess green space performance. These include: quantity and availability of urban green spaces (e.g., proportion of green space to total area), changes in green space, planning of green spaces (e.g., importance of green spaces to the city, existence of general goals and strategies for planning of urban green), financing of urban green spaces (changes in the budget for greenery), level of performance (success level of urban green space policy in light of objectives of the city). The results ranked the 24 cities in terms of combined indicators, revealing that cities with higher scores for indicators of availability of green space primarily determining the ranking.

This article is useful as it presents both a set of useful indicators for green space performance, as well as a means of combining qualitative and quantitative data to rank urban areas. As a method of incorporating qualitative and quantitative indicators into a composite index, this method has shortcomings in that typical of other Multi-criteria decision analysis (MCMA)methods, requires the input of stakeholders/expert opinion in order to develop a weighting vector to compare relative importance of indicators for green space performance.

Bjerke, T., et al. (2006). "Vegetation density of urban parks and perceived appropriateness for recreation." Urban Forestry and Urban Greening **5**(1): 35-44.

This paper aims to identify factors and value orientations that influence urban residents' recreational preferences for urban park landscapes varying in vegetation density. The primary motivation of this research is the growing evidence base indicating that exposure to nature has beneficial effects on human health, particularly for urban dwellers.

The study employed a survey issued to 1,500 residents in Trondheim, Norway. Respondents, along with supplying demographic information, were asked to rank pictures of nature scenes by the appropriateness of the scenes for recreation. The scenes varied in density of vegetation, to semi-open parks, to heavily vegetated reserves. The results highlighted that age, education, and interest in wildlife and the environment were important factors in respondent preferences, with middle-aged, well educated and eco-centric respondents favouring more heavily vegetated spaces for recreation.

While not strictly relevant to creating a metric for urban green space development, this paper highlights an added dimension to the discussion, which is preference for some elements of the community towards densely vegetated urban green spaces. Therefore, it is important to consider that urban green spaces should provide for a range of recreational preferences including densely vegetated parks, which themselves bring added benefit to urban ecosystem services.

Botequilha Leitão, A. and J. Ahern (2002). "Applying landscape ecological concepts and metrics in sustainable landscape planning." Landscape and Urban Planning **59**(2): 65-93.

This paper presents a framework for sustainable landscape planning utilising landscape ecological concepts and landscape metrics as ecological planning tools. The primary motivation of this research is the spatial aspects of sustainability.

The paper argues that ecological and urban/landscape planning have many common interests, therefore should share a common conceptual framework for future planning. The paper provides a broad literature review of bio-physical planning methodologies, including landscape planning, EIA, ecosystem management, rural planning, and sustainable land planning, and finds that landscape ecological metrics are useful tools in incorporating ecological knowledge into urban planning.

This is a useful paper, as it provides validity to expanding indicators for urban green space beyond bio-physical parameters such as percentage tree cover, to include more holistic indicators from other disciplines, such as ecosystem services. Holistically appraising urban green space in terms of different performance categories (e.g., bio-physical, ecosystem services, recreational, etc) is important, given the far reaching benefits of green space.

Cohen, P., et al. (2014). "A methodological approach to the environmental quantitative assessment of urban parks." Applied Geography **48**: 87-101.

This research presents a quantitative methodological approach, incorporating in-situ environmental measurements and data analysis to evaluate the impact of parks on urban environmental quality. The primary motivation of this paper is the difficulty in evaluating the overall influence of parks on urban environmental quality. The methodology proposed concentrates on three environmental nuisances: climate, air pollution, and noise, which were identified to have the greatest impact on urban park visitors.

The proposed methodology includes five stages: in-situ measurements of climatic, air pollution and noise variables; data analysis and indexing; data scaling; accumulative assessment of environmental nuisances, and; grading of overall environmental assessment for specific sites. All data collected was scaled so they could be compared. A grading was applied to assess which nuisance is more impactful in an area under investigation. The results of the application of this methodology show a clear superior environmental quality of parks compared to other urban areas across seasons. The results also show the identification of the nuisances that dominate environmental quality in the chosen investigation sites.

This paper is useful for MUGS, as it provides a methodology that incorporates environmental-focused indicators only that reflect primary drivers of urban environmental quality. The indicators used include air temperature, relative humidity, wind direction, wind velocity, global radiation, net radiation, carbon monoxide, nitrogen oxide, particulate matter, ozone, and noise. Considering findings from other papers, particularly in reference to assessing green space in regards to access and quality of vegetation, the methodology proposed perhaps is deficient as it does not consider these aspects. However, the indicators that are used have a strong connection to urban environmental quality, therefore should be considered in a MUGS.

Dan, H. and W. Ru-song (1998). "An integrated approach to evaluation on ecological service functions for urban green space and its application." Journal of Environmental Sciences **10**(3): 316-324.

This paper presents a conceptual approach for devising an index system for measuring integrated ecological service functions for urban green space, using an approach that integrates fuzzy mathematics and decision making analysis. The approach is applied to the land-use strategic planning for green spaces in the city of Tianjin, China. The primary motivation for this work, is that up to the period when this research was publish, most research in the measurement and evaluation of the benefits of UGS had emphasised the economic dimension, with little work focusing on social and natural dimensions. The motivations is then that an holistic approach for the measurement of the impacts of ecosystem service functions is required.

The approach used in this paper is based on the Delphi method of multi-criteria analysis. A hierarchy is developed consisting on 10 indicators grouped into economic-eco functions, social eco-functions and natural eco-functions categories. These indicators include output from urban green space, environmental amenity, landscape/visual value, and purification of urban bio-physical environment. AHP, a multi-criteria decision analysis (MCDA technique is employed, using weightings derived from experts and decision makers, to rank the importance of individual metrics, and is used in measuring the impact of ecosystem service functions for the Tianjin strategic plan.

This paper is useful in providing a way of ranking indicators for measuring the impact of green space. While the specific approach in this paper is not particular relevant, and perhaps outdated, the technique of using MCDA to rank individual metrics in their importance in measuring urban green space is very useful, and would certainly have application in a

MUGS by identifying the most important metrics, and as a way to incorporate stakeholder preferences.

de la Barrera, F., et al. (2016). "Indicators for green spaces in contrasting urban settings." Ecological Indicators **62**: 212-219.

This paper proposes several indicators for assessing urban green space, and are applied to two spatial scales under a multi-dimensional framework, taking into account human well-being advantages of green space. The primary motivation of this research is that metrics such as green space per capita do not provide enough information for effective decision making, and therefore effective tools are required to evaluate and better plan the location and quality of green space in urban areas.

Demographic, structural and remotely-sensed data are combined to develop a set of indicators to assess green space, with consideration to three main dimensions: quantity (indicators include green space per inhabitant, green space per bare soils), quality (e.g., mean size of green space, shape index of green space) and spatial distribution (e.g., share of population served by green space, aggregation index of green space).

The authors evaluate their findings and the indicators they proposed as an improvement over other metrics such as per capita green space when used to assess densely populated urban areas. While the indicators presented are no doubt useful, there is no discussion on evaluating green space performance by combining indicators into a single measure, nor is there discussion on which indicators are most crucial to urban green space. While not a limitation of the research, it is an area that could potentially be expanded if used to measure green space in Australia, under perhaps a multi-criteria decision support framework.

De Ridder, K., et al. (2004). "An integrated methodology to assess the benefits of urban green space." Science of the Total Environment **334–335**: 489-497.

This paper presents a methodology for evaluating the role of urban green space in alleviating the adverse effects of urbanisation, with consideration for socioeconomic aspects, and uses case studies of European cities to illustrate the methodology's use. The primary motivation of this piece is to evaluate the potential of cities in terms of green space enhancement, and to inform planning for effective implementation of green space provision while considering effects on socioeconomics.

The methodology employed by the authors is part of the Benefits of Urban Green Space EU research project. Maps are generated for the city under investigation, combining qualitative areal and remote sensing data which are used as inputs for further modelling (e.g., air quality and traffic modelling). Scenarios are developed in which urban green space is enhanced wherever possible, with results compared with the reference case. Results from analysis using this methodology are map outputs, identifying zones where green enhancement is possible and most desirable considering socioeconomic and health impacts.

This paper is useful, as it provides a methodology for assessing areas where green space additions would have the most beneficial public health and socioeconomic impacts. As a methodology informing a MUGS, the paper is not particularly relevant, as it does not present a methodology for measuring green space, or its impact, but it does provide more discussion around evaluation the benefits of UGS.

Derkzen, M. L., et al. (2015). "Quantifying urban ecosystem services based on high-resolution data of urban green space: an assessment for Rotterdam, the Netherlands." Journal of Applied Ecology **52**: 1020-1032.

This paper proposes a method for quantifying and mapping ecosystem services provided by urban green space using land cover data for Rotterdam, the Netherlands. This research is primarily motivated by available methods for quantifying ecosystem services not typically being used with high spatial resolution land cover data, which is needed for understanding ecosystem service supply in urban spaces.

A series of ecosystem service indicators of interest were determined (air purification, carbon storage, noise reduction, run-off retention, cooling, and recreation), with ecosystem service intensity for urban green space types (tree, woodland, tall shrub etc) determined based on literature. Spatial data sets describing the distribution of urban green space types in Rotterdam were then used to quantify ecosystem service. The key discussion point of this paper, is that it is important to delineate urban green space when assessing ecosystem service provision, as different types of green space provide different levels of ecosystem service. Therefore, quantifying ecosystem service per unit of urban green space does not fully consider variations of urban green space type. In order for this quantification however, high spatial resolution data is required, which is often not available or expensive to obtain.

This is a useful paper, with the method described applicable to both measuring ecosystem services and provides context for measuring different types of urban green space. The paper indicates the importance of delineating urban green space types.

Edwards, N., et al. (2013). "Development of a Public Open Space Desktop Auditing Tool (POSDAT): A remote sensing approach." Applied Geography **38**: 22-30.

This paper presents the development of a public open space desktop auditing tool that combines web-based information and remote sensing to assess the quality of green space cheaply without the need to on site auditing.

The hybrid method was developed using a combination of satellite and aerial imagery, in addition to local data sets. Audit variables and indicators measuring performance were identified from previous audit tools, and assess against available data sources for whether they would be included in the new developed tool. The audit tool is comprehensive, with over 30 indicators used to measure performance under auditing conditions. The study applied the tool across metropolitan Perth, and found that the tool gave good agreement when compared to previous audit methodologies.

This is a useful paper, presenting a tool that is used to assess the quality of urban green space. However, this tool is related to urban parks only, and not all urban green space, therefore may lose some applicability to a MUGS type tool. There is also little consideration for ecosystem service provision. The tool does present a possible framework for developing a tool however, or if MUGS tool is focused only on open green space, this tool would provide a good basis.

Ekkel, E. D. and S. de Vries (2017). "Nearby green space and human health: Evaluating accessibility metrics." Landscape and Urban Planning **157**: 214-220.

This paper reviews quantitative and qualitative aspects if green space accessibility metrics in relation to public health. This paper is primarily motivated by the strong scientific interest in the relationship between nature and human health, particularly in urban areas.

The authors focus on green space as opposed to 'nature' more generally, and discuss the dual issues of green space size and green space proximity in forming appropriate accessibility metrics for green space. The authors review empirical studies, and find that there are no clear cut-off values for distance to green space in the broader literature on accessibility, with loose definitions such as 'walking distance', and 300m direct line distance for example, used as a judge of green space within an accessible range for health benefits. A similar issue is presented by the authors in relation to green space size, with again there being no clear cut-off value for green space size for which health benefits can be attributed. The authors conclude that there are a large variety of accessibility metrics using a combination of distance and green space size in the literature, and variation makes it difficult to perform meta-analysis of the existing indicators. The authors do argue however, that more sophisticated accessibility indicators, i.e., that take into account more than simple distance and size metrics, are harder to use by practitioners in practice due to increased data requirements, and complex calculations required.

While this paper does not present quantitative indicators to be used in a metric for urban green space, it does present a qualitative evaluation of two common indicators used for accessibility. A key finding from this paper to be incorporated into a metric for urban green space is that variation in values used in empirical studies as identified by the authors suggests a degree of spatial specificity that needs to be acknowledged in formulating indicators for Australian urban spaces.

Frank, S., et al. (2012). "A contribution towards a transfer of the ecosystem service concept to landscape planning using landscape metrics." Ecological Indicators **21**: 30-38.

This paper presents a novel approach for assessing ecosystem services provided by green space by incorporating landscape metrics. The paper focuses on three ecosystem services: ecological functioning, aesthetic value, and economic wealth of the landscape. The primary motivation of this paper is the lack of studies which incorporate concepts of ecosystem services and landscape metrics, although since the time of this paper (2012), there have been several papers linking landscape metrics and ecosystem services.

The paper applies a modified set of ecosystem service indicators to a region in Saxony, Germany. Cellular automaton software was used to assess possible adaption strategies for the study area with the proposed assessment framework applied. The proposed assessment framework combines related landscape metrics with ecosystem service categories. Stakeholder participation was used to identify important indicators to be used. The results applied to an afforestation scenario derived from a cellular automata model showed that without the combined landscape metrics, the scenarios tested scored highly on a scoring system derived by the authors for ecosystem services. However by combining landscape metrics, the value for ecosystem service provision is much lower. This shows that under the conditions of this study, ecosystem service performance is highly sensitive to landscape metrics consideration.

Frank, S., et al. (2013). "Assessment of landscape aesthetics - Validation of a landscape metrics-based assessment by visual estimation of the scenic beauty." Ecological Indicators **32**: 222-231.

This article presents an objective assessment of landscape aesthetics, based on the use of well-known landscape metrics. The primary motivation of this research is that landscape aesthetics are perhaps the least formalised issue in the assessment of ecosystem services, as aesthetics cannot easily be quantitatively measured due to the subjective nature of aesthetics. The approach presented in this paper uses three landscape metrics: vegetation shape index, Shannon's diversity index (species diversity), and patch density. These metrics were transformed on a qualitative scale as an assessment of positive or negative impacts of the landscape's aesthetic value. To validate the objective approach, a questionnaire was also conducted to assess aesthetics.

This paper is useful as it presents a method for measuring landscape aesthetics. While aesthetics are important, they are not necessarily considered in other papers, potentially due to the subjective nature of beauty. If aesthetics is desired to be included in a MUGS, this paper presents a possible approach for its measurement.

Gidlow, C. J., et al. (2012). "Development of the Neighbourhood Green Space Tool (NGST)." Landscape and Urban Planning **106**: 347-358.

The aim of this paper is to develop a simple tool to characterise the quality of neighbourhood green space. The motivation behind this aim is that existing methods for assessing the quality of green space might not be appropriate for neighbourhood green space, as there are function al differences between small sites (that tend to serve local residents) and large sites (where people travel to visit). Using Stoke-on-Trent in the UK as a study area, a tool was developed through qualitative methods (focus groups, surveys). The tool developed contains a number of "domains" for assessing quality, each scored on a qualitative scale. These domains include: access (number of access points, pathways), recreation facilities (number of pieces of equipment, quality of equipment), amenities (provision/quality of seating, bins etc), natural features (quality of grass, trees and shrubs; water features), incivilities (extent of litter, vandalism, noise etc). The authors fund that the developed tool provides a simple and effective system to enable meaningful in-the-field assessment of urban green space quality.

This paper is useful as an effective, and simple method for measuring urban green space quality within a composite MUGS index. Indicators used by the authors could be incorporated quite easily into a composite system, and could be included as quantitative variables rather than qualitative scales also.

Gupta, K., et al. (2012). "Urban Neighbourhood Green Index - A measure of green spaces in urban areas." Landscape and Urban Planning **105**: 325-335.

This paper proposes an urban neighbourhood green index to be used as a simple tool, aimed at the objective assessment of urban green space and identifying areas for improvement at the neighbourhood scale. The primary motivation of this research is that measures such as percentage of green space or green space per capita are insensitive to spatial arrangement of neighbourhoods, e.g., when considering urban densification.

The method proposed combines several high resolution spatial data sets, used to classify vegetation from satellite imagery, as well as buildings. Indicators (percentage green space, built-up density, proximity to green space, and building height) are calculated, and combined with parameter weights derived through pairwise comparison, form the neighbourhood green index. The final output of this analysis is a mapping suite for urban green space quality, which takes urban neighbourhood structure into account.

This is a useful paper, presenting a relatively straight forward tool to assess urban green space with consideration of neighbourhood characteristics. The tool however relies on complicated analysis and data sets (i.e., vegetation cover or the estimation of vegetation cover from imagery, and building height information) which may not be readily available to users. A compromise to incorporate urban neighbourhood structure into a metric for urban green space could be the use of a population density metric, rather than raw population to calculate a green space per-capita metric.

He, J., et al. (2016). "Urban green space recreational services assessment and management: A conceptual model based on the service generation process." Ecological Economics **124**: 59-68.

This paper presents a conceptual model for assessing recreation services in urban green spaces based on ecosystem service generation. The paper explores factors that contribute to the use of urban green space and the benefits derived from recreational use of urban green spaces, and recommended indicators for measuring the benefits of urban green space.

The paper is conceptual and does not offer an empirical model, nor application of a set of indicators for assessing urban green space benefits. However under the conceptual framework of this paper, it does discuss a set of possible indicators in addition to how such indicators can be obtained (e.g. through GIS), specifically for measuring the recreational benefits of green space. Such indicators include quantity indicators (green space area, green coverage rate, etc.); distribution indicators (diversity, evenness, etc.); quality indicators (proportion of natural area, proportion of evergreen plants, presents of water features, stewardship, etc.). This paper can be considered useful for the development of an Australian MUGS by presenting possible indicators if recreation benefits would be included as a metric of green space performance.

Heckert, M. and C. D. Rosan (2016). "Developing a green infrastructure equity index to promote equity planning." Urban Forestry & Urban Greening **19**: 263-270.

This research develops an equity index for green infrastructure planning, with consideration for both direct and indirect benefits of green infrastructure to identify areas (in Philadelphia, USA) for green infrastructure investment. The primary motivation of this research is the promotion of green infrastructure as a storm water management technique, and to inform the future planning of distributed, urban environmental management systems.

The development of the green infrastructure equity index is based on calculating a composite measure of need, deprivation and risk. The developed index is at the census block spatial scale, and includes a number socioeconomic and environmental measures to represent at-risk populations and to compare relative disadvantaged areas. Measures were standardised and summed to produce a single index measure indicating areas at most disadvantage with little access to green infrastructure.

This paper is useful for determining metrics for urban green space that take account of socioeconomic advantage/disadvantage, but does not strictly provide a measure for assessing the performance of green space. Areas can be identified using a similar index where green infrastructure augmentation may have the most impact on local socioeconomics however, and this is valuable when considering urban green space in a holistic, urban sustainability lens. Moreover, by using different sets of variables, or combining with other performance metrics, indices could be developed that take into account ecosystem services performance in addition to socioeconomic and environmental health benefits.

Higgs, G., et al. (2012). "Investigating the implications of using alternative GIS-based techniques to measure accessibility to green space." Environment and Planning B: Planning and Design **39**: 326-343.

This paper explores the use of alternative distance metrics in indicators for accessibility to urban green spaces using GIS. A principle motivation behind the paper is the commonly used Euclidean distance measure in GIS approaches for assessing distance and accessibility of urban green space, and its limitations in terms of accuracy.

For this paper's approach, 6 proximity measures were tested, using either Euclidean or network distance, and were compared. The research found that the use of different proximity indicators and distance measures resulted in different accessibility measures. This is particularly important when considering nearest green space, which depending on the chosen distance measure, will give different outcomes. The researchers of the paper also argue that although network based distance is more accurate, distance measures only approximate levels of exposure to green space in the public health context, and is only one contributor of many in assessing green space accessibility and public health implications.

This paper is useful as it gives consideration to selecting appropriate distance measures when assessing accessibility. This paper does not provide a standalone indicator, or an approach for determining an indicator set. Rather, it provides a discussion of deriving distance based indicators.

Jorgensen, A. and P. H. Gobster (2010). "Shades of green: Measuring the ecology of urban green space in the context of human well-being." Nature and Culture **5**(3): 338-363.

This paper provides a review and analysis on recent academic literature on attempts to measure biodiversity and other green space concepts relevant to urban ecological restoration. The primary motivation of this paper is the importance of effectively measuring green space qualities and characteristics foe health and well-being outcomes, and selecting appropriate measures for desired health and well-being outcomes.

The authors conduct a broad literature review of relevant academic papers, and develop a taxonomy for classifying urban green space measures based on the literature reviewed. Measures reviewed is then classified according to the developed taxonomy. Classes within the taxonomy include: urban versus natural (comparison between urban and natural settings), descriptive/narrative (qualitative description of green space), inventory (multiple characteristics including vegetation and facilities), area/distance (quantity or proximity of green space), bio-physical (e.g. presence and quantity of specific landscape elements), human perceptual (e.g. categorisations based on cultural constructs/values), and biodiversity (objective measure of plant/animal diversity). Reviewed studies were then mapped against a similar taxonomy for health and well-being indicators, to highlight the diverse ways in which researchers measure green space and relevance to human health.

This paper is a qualitative paper, and does not offer specific measures that can be readily utilised in a MUGS for Australian green space. The discussion around the types (or taxonomy) of measures of green space is interesting, measures belonging to the "inventory" taxonomy would be of particular benefit for developing a MUGS. This paper also highlights the complexities in selecting measures for green space characteristics, as different outcomes (e.g., biodiversity outcomes vs public health outcomes) of green space may have very different appropriate measures of quality and performance.

Kaczynski, A. T., et al. (2016). "ParkIndex: Development of a standardized metric of park access for research and planning." Preventive Medicine **87**: 110-114.

This research develops and demonstrates an empirical and spatially-represented, standardised index/metric for urban green space (parks) access. The primary motivation of the authors was to develop a common and simple measure for urban green space to facilitate further research, planning and advocacy from local stakeholders in the study area (Kansas City, Missouri, USA).

The research analyses survey data from a number of local residents and park users, in addition to GIS data for park locations. Summary variables are derived (number of parks, distance to closest park, total park area and average park quality) and used in a logistic regression analysis, controlling for demographics, to determine which summary variable is most associated with park use. Two of the summary variables (number of parks, and park quality) were found to be statistically significant. Coefficients from the regression model were combined in a 100m x 100m raster representation of the study area to determine the ParkIndex indicator, which represents a standardised measure of park access and exposure across the study area.

While this paper does not strictly discuss the performance of urban green space, or indicators to measure its performance, it does give a spatial index for determining areas with high/low accessibility to urban green space. The nature of the publication that this research appears in (Journal of Preventive Medicine) shows the potential application of such an index when health related measures are considered alongside access to public open green space. This paper can inform the design of an accessibility-type metric that can be used for further analysis, or as a standalone, easy to compute, metric for accessibility.

Koc, C. B., et al. (2016). "A green infrastructure typology matrix to support urban microclimate studies." Procedia Engineering **169**: 183-190.

This paper presents a standardised classification scheme (or typology) to classify urban green infrastructure to inform climate analysis of green infrastructure at different scales and at different locations. The primary motivation of this research is mitigating the impacts of the urban heat island effect from proliferating urban sprawl, and to consider green infrastructure from a climatological perspective. The scope of green infrastructure in the context of this paper include tree canopy, green open spaces, green roofs, and vertical greenery systems.

The research examines the literature to survey classification schemes used to classify and describe green infrastructure. From the existing classification schemes, a new scheme is proposed, which is more specifically aimed at climatological aspects of green infrastructure. The proposed typologies for green infrastructure is a double-entry matrix, with 14 classes and 23 sub-classes, of vegetation, ground surfaces and building surfaces. This matrix allows the classification of combinations of vegetation, ground surfaces and building surfaces into logically structure typologies, where climate profiles can be assumed to facilitate further analysis.

This paper is useful in providing a discussion of classifications of urban green infrastructure in the context of climatology. While this paper does not strictly refer to urban green space, its definition of green infrastructure includes only aspects of green cover, for example, roof top gardens in addition to open space and urban vegetation, therefore is relevant to the discussion of MUGS. While no direct discussion is present on metrics and indicators for green space, the paper makes a clear link to the cooling aspects of green infrastructure in mitigating urban heat island effects. This paper can potentially inform the inclusion of a green infrastructure metric/indicator into a MUGS.

La Rosa, D. (2014). "Accessibility to greenspaces: GIS based indicators for sustainable planning in a dense urban context." Ecological Indicators **42**: 122-134.

This paper is aimed at developing a set of urban green space accessibility indicators using GIS to inform urban planning in a city in Southern Italy.

The indicators used to quantify accessibility are divided into two types: distance measures, and proximity measures. Distance measures are simply based on the distance relationship between UGS users and the UGS itself, and proximity measures are weighted distance measures. Both approaches require sub-indicators, namely points representing the locations of users, points representing the location of UGS services, and distance measures between these points. An added component of this paper is the evaluation of different distance measures; namely Euclidean distance, and Network distance. Accessibility measures using network distance were found to be lower, however better reflect local geographies of transport. The downside of using the network distance measure is the requirement for greater data sets.

This is a useful paper, giving a purely bio-physical, accessibility indicator for urban green space. While on its own, the proposed method in this paper is lacking when considering other aspects of green space such as ecosystem services, the indicators proposed in this paper can be easily incorporated into composite metrics when consideration of bio-physical accessibility is required.

Mills, J. R., et al. (2016). "Urban forests and social inequality in the Pacific Northwest." Urban Forestry & Urban Greening **16**: 188-196.

In this paper, urban forest data is analysed along with local socioeconomic data to determine what socioeconomic characteristics best explain local urban greenness in the Pacific Northwest USA. Indicators used as measures of greenness include canopy cover presence, percent canopy cover, number of trees, and number of tree species.

Urban forest data was collected in-situ using methods applied typically to forested areas. Random "plots" were placed over the study area, with each plot consisting of 4 subplots. Trees located within these 4 subplots at each plot where sampled to form the inventory of urban forest data. Tree data was analysed with socioeconomic data using regression. Results found that socioeconomic indicators do explain variation in urban greenness.

This paper offers usefulness as an in-site sampling method to collect urban vegetation data. In addition, the paper is further evidence of the relationships between socioeconomics and urban greenery.

Neuenschwander, N., et al. (2014). "Integrating an urban green space typology into procedural 3D visualization for collaborative planning." Computers, Environment and Urban Systems **48**: 99-110.

This paper presents a tool for visualising the ecosystem service benefits brought by urban green space. The tool presents generic typologies of green space and linked with information on the potential ecosystem services, combined with stakeholder engagement.

This paper does not strictly present a method or tool for measuring urban green space, or the performance of urban green space. It is useful however as it does supply a number of ecosystem services investigated, and indicators. Ecosystem services investigated and indicators include microclimate regulation (number of trees, sum of vegetated land); water flow regulation (sum of unsealed areas); recreation (sum of public green spaces); food and wood production (number of fruit trees, sum of agricultural areas); habitat for species (amount of trees, ratio of coniferous and deciduous plants, sum of potential habitat areas), and place attachment and community cohesion (size of green space, average size of public green spaces). The indicators presented in the paper might be useful in devising composite indicators for urban green space performance

Pakzad, P. and P. Osmond (2016). "Developing a sustainability indicator set for measuring green infrastructure performance." Procedia - Social and Behavioural Sciences **216**: 68-79.

This paper presents an exploratory study on developing a new conceptual framework for assessing green infrastructure sustainability performance.

Assessing sustainability performance based on measurable indicators is complex, yet critical for urban sustainable development. Firstly, the authors critically examine existing frameworks and indictors for urban sustainability and green infrastructure. This evaluation informs the development of a new framework for selecting green infrastructure indicators that reflect the comprehensive and integrated function of green infrastructure for urban sustainability.

To further develop this new framework and indicator set, a series of stakeholder interviews were performed with Australian experts, where they were asked to identify the main benefits of green infrastructure.

The conceptual framework developed provides a basis for establishing a composite indicator-based model for assessing green infrastructure sustainability performance. 30 indicators were selected based on the comprehensive review of existing frameworks and the stakeholder interviews. These 30 indicators are broken down into 4 categories that describe the performance of green infrastructure on urban sustainability: ecological indicators (e.g., climate modifications, air quality improvement, reduced building energy use); health indicators (e.g., improvements in bio-physical and mental well-being); socio-cultural indicators (e.g., accessibility, crime reduction), and; economic indicators (e.g., property values, value of avoided energy/CO2 emissions).

This paper is useful for linking urban green space with various bio-physical and socioeconomic performance indicators. It is useful for developing a tool that considers these complex factors in the provisioning of urban green space, however does not strictly present metrics or indicators for assessing the performance of urban green space independently.

Saarela, S.-R. and J. Rinne (2016). "Knowledge brokering and boundary work for ecosystem service indicators. An urban case study in Finland." Ecological Indicators **61**: 49-62.

This paper applies a set of GIS-based ecosystem service indicators to a Finnish city and municipality in a group collaboration exercise with local stakeholders. The motivation behind this research is the development of effective indicators harnessing active knowledge brokering on local government and relevant planning and environment issues and policies. Comprehensive indicators were applied to study green infrastructure and ecosystem services using GIS, with stakeholders engaged in the interpreting of results and on applying existing ecosystem service indicator methodology. Ecosystem service indicators were applied depending on the geographic application, and include indicators such as proportion of uniform forest areas, proportion of ecological connections, proportion of land areas suitable for recreation, and the proportion of residents living within accessibility to recreation zones.

This is a useful paper as it outlines an approach for engaging with stakeholders in the development of an indicator set based on knowledge brokering, as well as how to interpret results. The indicators present in this paper are perhaps less relevant for Australian urban cities, given their levels of urban/suburban development, however the approach of using an integrated GIS-stakeholder engagement/group modelling style analysis is useful.

Vallanueva, K., et al. (2015). "Developing indicators of public open space to promote health and wellbeing in communities." Applied Geography **57**: 112-119.

This paper proposes a method to develop a set of public open space indicators from a public health and wellbeing perspective, by developing a framework for the pathways in which open space influences health, and using the framework as a guide to identify up-stream policy relevant indicators. 11 potential indicators and spatial measures are proposed based on Australian data. The proposed indicators act to benchmark and measure neighbourhoods in terms of public open space provision, thereby allowing for the identification of neighbourhoods where liveability and public health can be improved.

The set of proposed indicators is based on a systematic review of literature (grey and academic) and policy documents. The final set of proposed indicators are based on public open space quantity (percentage open space area, number of public open spaces, etc.); public open space access (road network distance to public open space, number of dwellings with access to different sizes of open space); and public open space quality (a derived attractiveness score, based on remote sensing methods). The indicators presented are not used in further analysis, however the paper proposes their use in combining with socioeconomic and health/well-being data to better describe the variation of public open space on public health.

This paper is useful in that it provides an Australian context to the issues of urban green space metrics, with particular reference to local policies. The selection of indicators could be improved (i.e., with the addition of accessibility metrics, or more specifics to urban green space such as vegetation diversity).

Van Den Bosch, M. A., et al. (2016). "Development of an urban green space indicator and the public health rationale." Scandinavian Journal of Public Health **44**: 159-167.

The aim of this paper is to develop and test a methodology for an urban green space indicator for public health, to be used as a proxy measure for assessing public accessibility to urban green spaces; to provide comparable data across Europe, and to simulate urban policy discussions. The primary motivation of this work is to support health and environmental policies given the many positive contributions urban green space makes to public health.

The methodology proposed by the authors combines land cover, urban green space, and population data sets in a GIS system, and using 'buffer analysis', determines an urban green space indicator reflecting the percentage of urban residents for whom green space is accessible. The methodology is tested across three European cities (Malmo, Kaunas, and Utrecht).

This is a useful paper, as it proposes a methodology for measuring urban green space motivated by public health benefits, that is designed to be simple and general enough for providing estimates of green space accessibility across multiple cities. As an indicator of urban green space, the proposed metric is perhaps overly simplistic, not taking into account population densities or variations in socioeconomic and bio-physical factors influencing green space accessibility and coverage.

Van Herzele, A. and T. Wiedemann (2003). "A monitoring tool for the provision of accessible and attractive urban green spaces." Landscape and Urban Planning **63**: 109-126.

This paper presents an integrated indicator for monitoring urban green space provision against targets, and for comparison between cities and areas within cities. The proposed indicator is also designed to assess effects of future city planning policy scenarios and to identify locations were action is required. The key motivation and aim of this paper was to develop an indicator to measure progress towards sustainable green supply in Flemish cities over time. Green space quality is the primary performance indicator of interest

GIS is utilised to measure indicators. Parameter sets used to evaluate attractiveness of urban green space include space, nature, culture and history, quietness and facilities. The indicator set proposed includes sub-indicators for each indicator related to quality.

While not completely relevant to measuring urban green space, this paper is useful as it does provide a useful conceptualisation of how attractiveness can be used as a measure for urban green space importance. The methods used in this paper are similar to other papers, therefore does not offer any significant learnings to measuring urban green space other than using attractiveness as a metric.

Xu, L., et al. (2016). "Urban green spaces, their spatial pattern, and ecosystem service value: The case of Beijing." Habitat International **56**: 84-95.

This paper studies the relationship between the spatial pattern of urban green space, and the ecosystem service value they convey in terms of real estate value. Spatial characteristics used in the authors' analysis consist of green space richness, accessibility, distribution and shape. These characteristics are used in a Hedonic price model to separate out the green space premium from residential real estate prices. This creates a proxy measure of the value of green space in relation to local property prices in Beijing, China.

The paper presents the landscape ecological metrics used to determine the spatial characteristics of urban green space. These are formally defined as richness (the ratio between urban green space and the whole landscape area), accessibility (distance from a real estate site to the nearest urban green space patch), distribution (a measurement of the fragmentation level of urban green space in a certain area), and shape configuration (ratio of the perimeter of a green space patch and the minimum perimeter of a green space patch possible - a value of 1 indicates a perfectly square patch, with values higher than 1 indicating increasingly complex shapes). Results of the modelling show that distance from an urban green space patch to a real estate site determines if the green space's ecosystem service value influences real estate prices. Results also show that an optimal level of spatial fragmentation of green spaces maximises this effect.

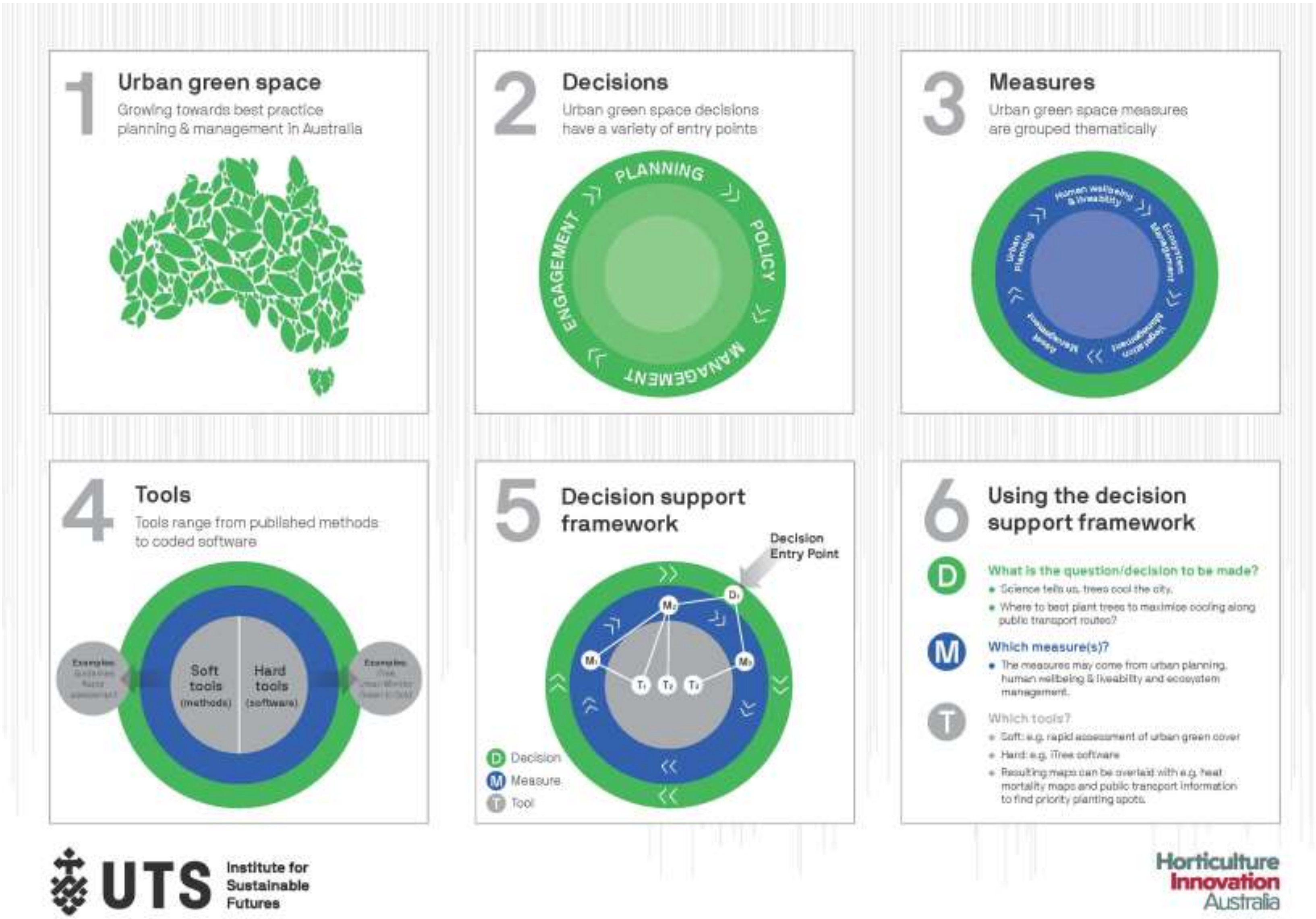
This is a useful paper, presenting a series of potential indicators that can be incorporated into a metric for urban green space. Moreover, the relation between ecosystem service value and real estate prices may be particularly interesting in relating ecosystem service value to a more meaningful scale of value, proportional to local real estate value.

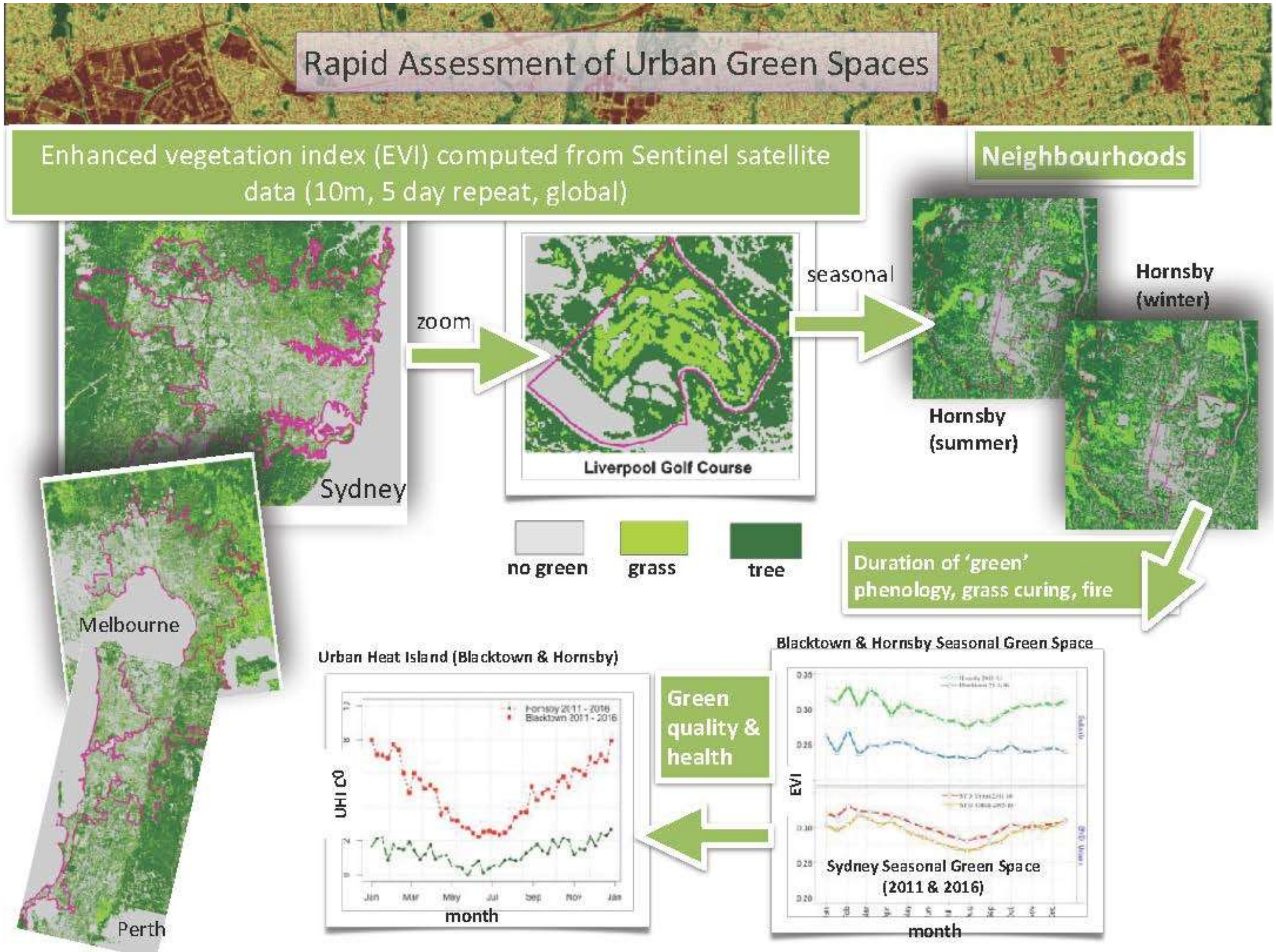
Yao, L., et al. (2014). "Effective green equivalent - A measure of public green spaces for cities." Ecological Indicators **47**: 123-127.

This paper proposes a metric of effective green equivalent--a measure of urban green space corrected for quality and accessibility. This research is primarily motivated by the deficiencies of the green space-per capita metric prevalent in the measurement urban green space. This study is specifically focused on public green space therefore the per capita metric is not a sound indicator of urban green space performance and accessibility. The indicator developed by the authors considers green space quality and accessibility in relation to residential public green space resources. Three new indicators are developed: effective green equivalent, average EGE, and an inequality coefficient, and are applied to the city of Beijing. The indicator presented in this paper is a function of the area of public green space, its quality and accessibility. Estimates for quality and accessibility are derived from NDVI estimates and mathematical modelling, relating resident distance to green space.

This paper is useful as it presents an adaptable indicator for evaluating urban green space. The indicator is able to provide planners and decision makers with quantifiable goals with consideration to both quality and accessibility, which are sometimes ignored in measuring green space performance. The methodology described can be applied across varied urban localities given the generalisations of the modelling, however a degree of mathematical insight and expertise is required, potentially limiting its applicability for decision makers without quantitative backgrounds.

Appendix J   Blueprint





Rapid Assessment of Urban Green Spaces
Enhanced vegetation index (EVI) computed from Sentinel satellite data (10m, 5 day repeat, global)
Neighbourhoods
Sydney
zoom
Liverpool Golf Course
seasonal
Hornsby (summer)
Hornsby (winter)
Melbourne
Perth
no green
grass
tree
Duration of 'green' phenology, grass curing, fire
Blacktown & Hornsby Seasonal Green Space
EVI
Sydney Seasonal Green Space (2011 & 2016)
month
Green quality & health
Urban Heat Island (Blacktown & Hornsby)
Hornsby 2011 - 2016
Blacktown 2011 - 2016
UHI C0
month

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