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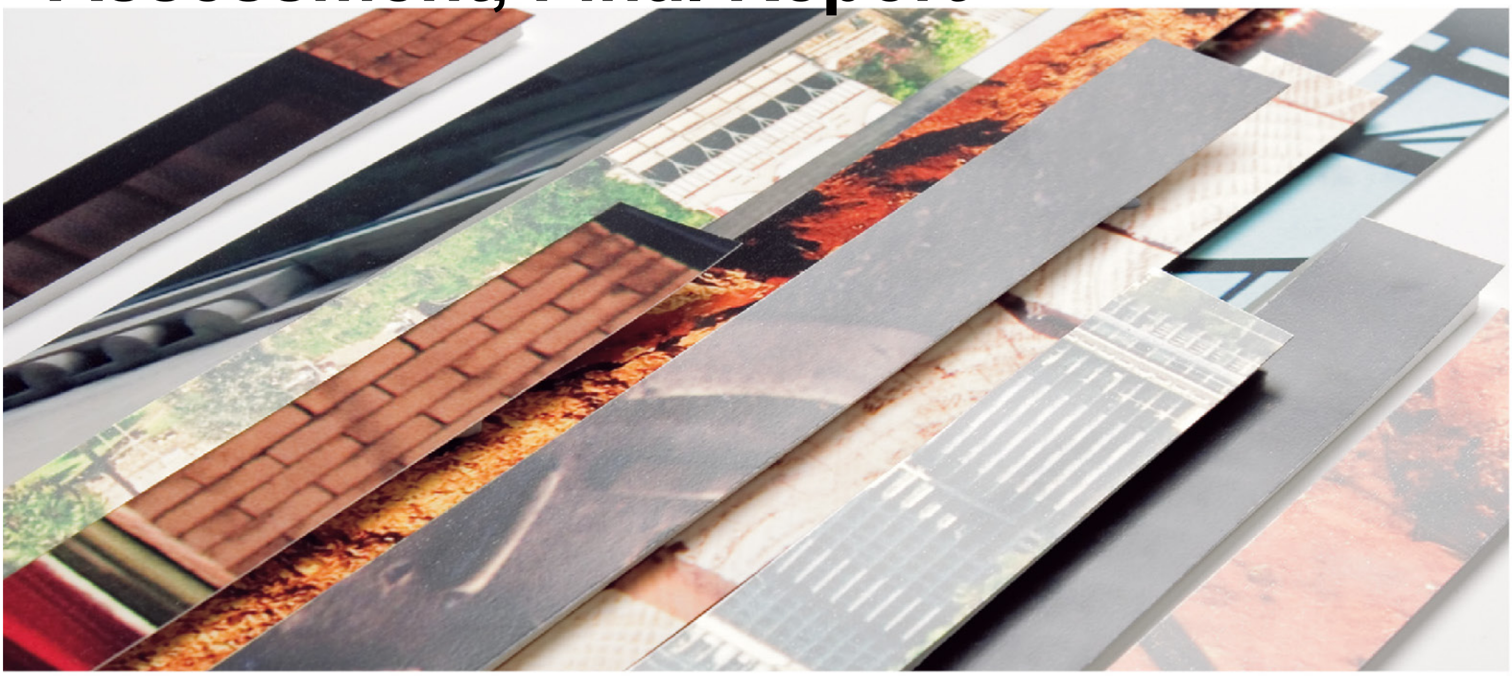
Benchmarking Australia's Urban Tree Canopy: An i-Tree Assessment, Final Report



2014

ABOUT THE AUTHORS

The Institute for Sustainable Futures (ISF) was established by the University of Technology Sydney in 1996 to work with industry, government and the community to develop sustainable futures through research and consultancy. Our mission is to create change toward sustainable futures that protect and enhance the environment, human well-being and social equity. We seek to adopt an inter-disciplinary approach to our work and engage our partner organisations in a collaborative process that emphasises strategic decision-making.

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Final Report
Benchmarking Australia's Urban Tree Canopy: An i-Tree Assessment

Prepared for: Horticulture Australia Limited

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1 INTRODUCTION

This report aims to provide 139 Local Governments in urban and semi urban environments across Australia with an estimate of land surface cover. This study is part of the 202020 Vision (http://202020vision.com.au/) funded by Horticulture Australia Limited, in working towards a 20% increase in the level of green space in Local Government Areas (LGAs) across the country.

Benefits of Green-space

Vegetation in urban landscapes or Urban Green Space (UGS) is known to provide multiple benefits that encompass biophysical, economic and social attributes. These benefits include:

- Maintenance of habitat for native fauna, which can include vulnerable or threatened species in fragmented urban landscapes.
- Reduction of the urban heat island effect, which is also an important climate change adaptation strategy.
- Improvements in air quality.
- Improvements in storm water management through reductions in the extent of hard impervious surfaces.
- Provision of spaces for interaction, amenity and recreation, which improve community health and social well-being.
- Provision of beneficial visual stimulus for urban residents.

In light of the multiple benefits associated with retaining green cover within urban landscapes, quantifying UGS in Australian cities (and urban Local Government Areas in particular) may act to motivate councils and developers to increase green-infrastructure in the interests of sustainable development. Green cover metrics that provide rapid, low-cost measures of UGS are essential to promote urban sustainability. The metrics used in this report offers an opportunity to benchmark green cover among the major urban areas nationally and support the 202020 Vision.

Background

Existing vegetation maps do not provide adequate baseline data regarding the extent of green cover across major Australian cities. Much of the data underpinning such maps is determined from remotely sensed satellite imagery, which is expensive to purchase, and requires specialised skills in the use of GIS software to manipulate. In addition, data to monitor land use often fails to keep pace with the rate of change in urban environments (Musakwa and Niekerk 2013), where urban in-fill and expansion of the built environment into peri-urban spaces can occur rapidly. The i-Tree suite of free online tools provides a low cost, rapid and repeatable method for assessing canopy cover.

Report Outline

This report provides the results from the i-Tree mapping of UGS of 139 LGAs across Australia. Section 2 details the methodology used to map each LGA. Sections 3-10 present the results for each State or Territory, providing a ranking, coded maps, and league table for the selected LGAs. Section 12 provides a high level discussion of the results and outlines key consideration and further research opportunities.

Categorisation systems for green space can be unclear and overlapping which has made it difficult to plan, design and compare green spaces (Aldous, 2013). For the purpose of this analysis, land cover has been categorised into the following groups;

- Tree cover
- Shrub cover
- Grass and/or bare ground
- Hard surfaces

There are two primary reasons for this categorisation; function and opportunity. While trees and shrubs can be defined as green space (as can grass), they each serve a different ecological function. Providing a more granular analysis that distinguishes between trees and shrubs enables LGAs to gauge the different proportions of ‘green spaces’ rather than grouping all levels of green cover as a single unit. Similarly, the distinction between grass and hard surface is important from an opportunity perspective. Depending on the definition of green space, grassed areas can often fall into this broad categorisation. For the purpose of this analysis, distinguishing between grass/bare ground and hard surfaces can provide a high level understanding of what proportions of surface cover can be utilised as potential planting areas. Understanding the proportion of hard surfaces can help councils gauge where more innovative means of urban green space can be utilised, such as green walls and roof top gardens.

It is important to note the significant biophysical, geographic and institutional variations at state and local government level that influence the current levels of canopy cover and opportunities increasing these levels. This study provides a high level, indicative assessment of current ground surface cover designed to catalyse a process of social change through benchmarking (for a review see Huggins 2010).

This report is the first step in strengthening an understanding of the composition of land cover and how urban greening strategies can be maximised in urban areas of Australia. There is a great deal of further research that can work to enhance this understanding and guide practical responses to urban greening efforts. The recommendations for further research, which build on the analysis presented in this report, are detailed in the discussion.

2 METHODOLOGY

A 1000-point random sample method was used to classify landscape features within 139 urban/suburban/peri-urban Local Government Areas throughout Australia. These Local Government Areas were generally located in and around the Greater Capital City region within each State and Territory, as this is where the major changes in land cover coincide with high human population densities likely to be affected by loss of tree cover. A number of additional LGAs were included in the study, such as Newcastle (NSW) and Geelong (VIC), as certain urban and suburban areas exist outside of the Greater Capital City regions within important regional centres.

Table 1: Number LGAs for each State included in study

State	Number of LGAs	Date of imagery[1]
New South Wales	39	2009
Victoria	34	2013
Queensland	10	2009
South Australia	19	2013
Western Australia	29	2011
Northern Territory	2	2009
Tasmania	5	2008
Australian Capital Territory	1	2008
Total	**139**	

[1]Variations in date of imagery are acknowledged as a consideration in the interpretation

i-Tree Canopy Software

A free-use software tool called *i-Tree Canopy* was used to generate the 1000-point random sample within each LGA boundary. This online tool draws on Google Earth imagery overlayed with shape-file boundaries. In this case, the 2011 ESRI shape-file boundaries for Australian Local Government Areas were downloaded from the Australian Bureau of Statistics. The selected shape-files were then exported from this dataset using Quantum GIS (http://www.qgis.org/en/site/), before finally being loaded individually into the *i-Tree Canopy* tool.

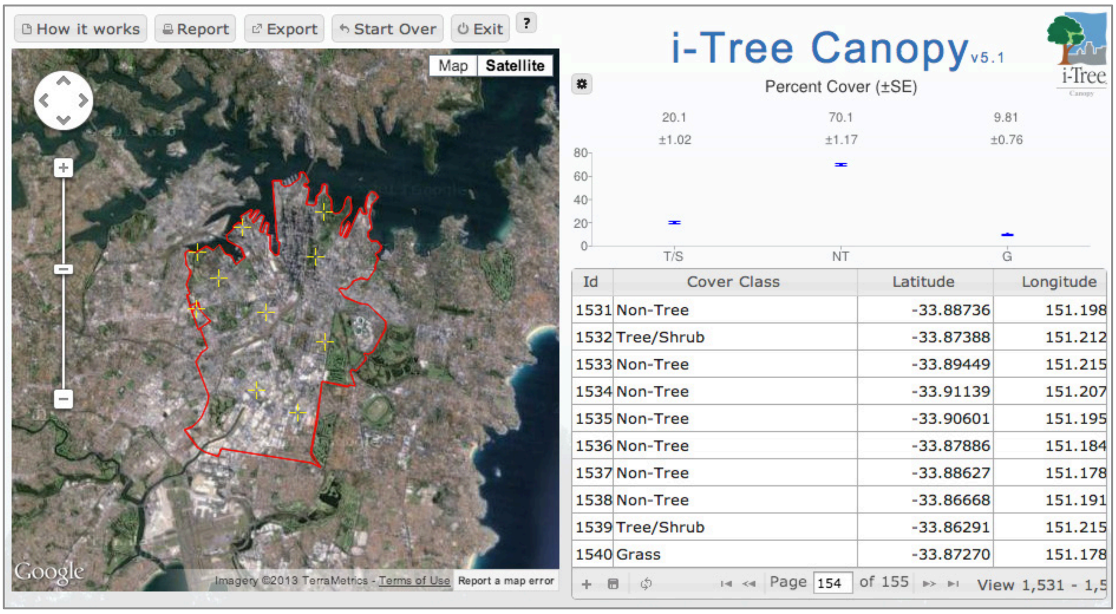
The background to iTree canopy software extracted from the iTree website
(http://www.itreetools.org/about.php)

i-Tree is a state-of-the-art, peer-reviewed software suite from the USDA Forest Service that provides urban and community forestry analysis and benefits assessment tools. The i-Tree tools help communities of all sizes to strengthen their urban forest management and advocacy efforts by quantifying the environmental services that trees provide and the structure of the urban forest.

Developed by USDA Forest Service and numerous cooperators, i-Tree is in the public domain and can be downloaded for free. The Forest Service, Davey Tree Expert Company, National Arbor Day Foundation, Society of Municipal Arborists, International Society of Arboriculture, and Casey Trees have entered into a cooperative partnership to further develop, disseminate and provide technical support for the suite. See the System Requirements and Installation document for registration, download and installation details.

Full details of the technical aspects of the i-Tree Canopy including user manuals are available at: http://www.itreetools.org/resources/index.php

Figure 1 Example of analysis boundary within i-Tree canopy - City of Sydney



The software calculates the results throughout the interpretation process, with the final estimations viewable as either *Cover Percentages* or *Cover* Area (km²). Importantly, the more random points sampled, the lower the estimated *Standard Error,* and the more precise the estimated result. Previous authors (e.g. Richardson and Moskal, 2013) in a comparison of canopy estimation techniques concluded that all techniques included uncertainty. They provided a list of recommendations for those undertaking canopy cover assessment in complex urban environments. With those recommendations in mind, Jacobs and Mikhailovich (2013) conducted a brief scoping study to evaluate the i-Tree Canopy tool, as a potential method to obtain standardized baseline data on urban green cover. The scoping study determined that logging 1000 points for each LGA gave *cover percentage* estimates that stabilised somewhere between 600-1000 points (showing variation based on the size of the LGA) with a maximum predicted standard error of <3.0%. For all but the largest LGAs the standard error was in effect even smaller in the range of 0.01-2.0%.

The *i-Tree canopy* user must clearly define the appropriate landscape features or '*cover classes'* to classify. The number of classes is also important to consider as adding more categories can increase the number of points needed to achieve statistical stabilization of the cover estimates. Table 2 explains the cover classes selected for this study. The i-Tree software effectively uses a point-quadrant technique, commonly used to assess vegetation composition, on the projected canopy generated through Google Earth imagery.

Table 2: Classification of surface cover

Cover Class	Abbreviation	Description
Hard surface	HS	Currently non-plantable
Tree	T	Canopy cover
Shrub	S	Understory
Grass - Bare ground	G/BG	Potentially plantable

All landscape features were categorised into one of these four categories when viewing the LGAs through Google Earth imagery. The number of categories or cover classes that could be included in the analysis was heavily constrained by budget. Accordingly, some features such as sandy beaches, water bodies and rocky coastlines, which make up relatively small proportions of land cover were included in *Hard Surface*. Although water bodies are strictly speaking not developed hard surfaces, they are nonetheless *'currently not-plantable'*. It is also important to understand that existing land use contexts did not influence the cover class classification, in the sense that it only took into consideration what the surface was, but not how it is currently being used or whether the land was private or publicly owned. To explain further, all grass surfaces were considered to be '*potentially plantable'* even though it is unrealistic to think that sporting fields or airports for example would be suitable locations for new plantings in the near future. In the same way, hard surfaces are described above as '*currently non-plantable'*, however many councils open footpaths with concrete cutting equipment to insert new street plantings, so the context can change over time. The key point to remember is that the same standards were applied to all LGAs and the most relevant measure that the study aimed to identify was tree canopy cover. All tree classifications were simply that, objects recognisable from above as trees. Table 3 expands on some of the common surfaces classified into each category.

Table 3: List of categorised surfaces

Grass & Bare Ground	Hard surfaces	Tree	Shrub
○ Agricultural pasture ○ Residential lawns ○ Cleared areas to the sides of roads and railway tracts ○ Golf Courses ○ School Ovals ○ Airports ○ Sports Fields ○ Cemeteries ○ Horse racing tracks ○ Lawn Bowls ○ Grass Tennis Courts ○ Industrial estates ○ Sites cleared for development	○ Buildings ○ Roads ○ Footpaths ○ Train lines ○ Car parks ○ Water bodies ○ Sandy beaches ○ Rocky coastlines	○ Anything that looks like a tree from above. ○ Often differentiated from a shrub by the shadow cast by the elevated canopy.	○ Included landscaped vegetation as well as bush land shrubs ○ Agricultural crops such grape vines were also considered shrubs

○ Dirt roads and walking tracks			

A noteworthy anomaly with the *i-Tree Canopy* method is that at times the imagery for bush land reserves is of a poorer quality than that which is available for urban areas. Accordingly it may be challenging to differentiate shrubby heath from grassland, or, taller shrub land from juvenile woodlands for example. Fortunately, most LGAs have already been updated with better quality imagery. Errors are accounted for by the *standard error* estimation within the tool, and the fact that the study was over sampling all but the largest LGAs, as the stabilisation point for cover percentage estimates generally came well before 1000 points were classified for most LGAs.

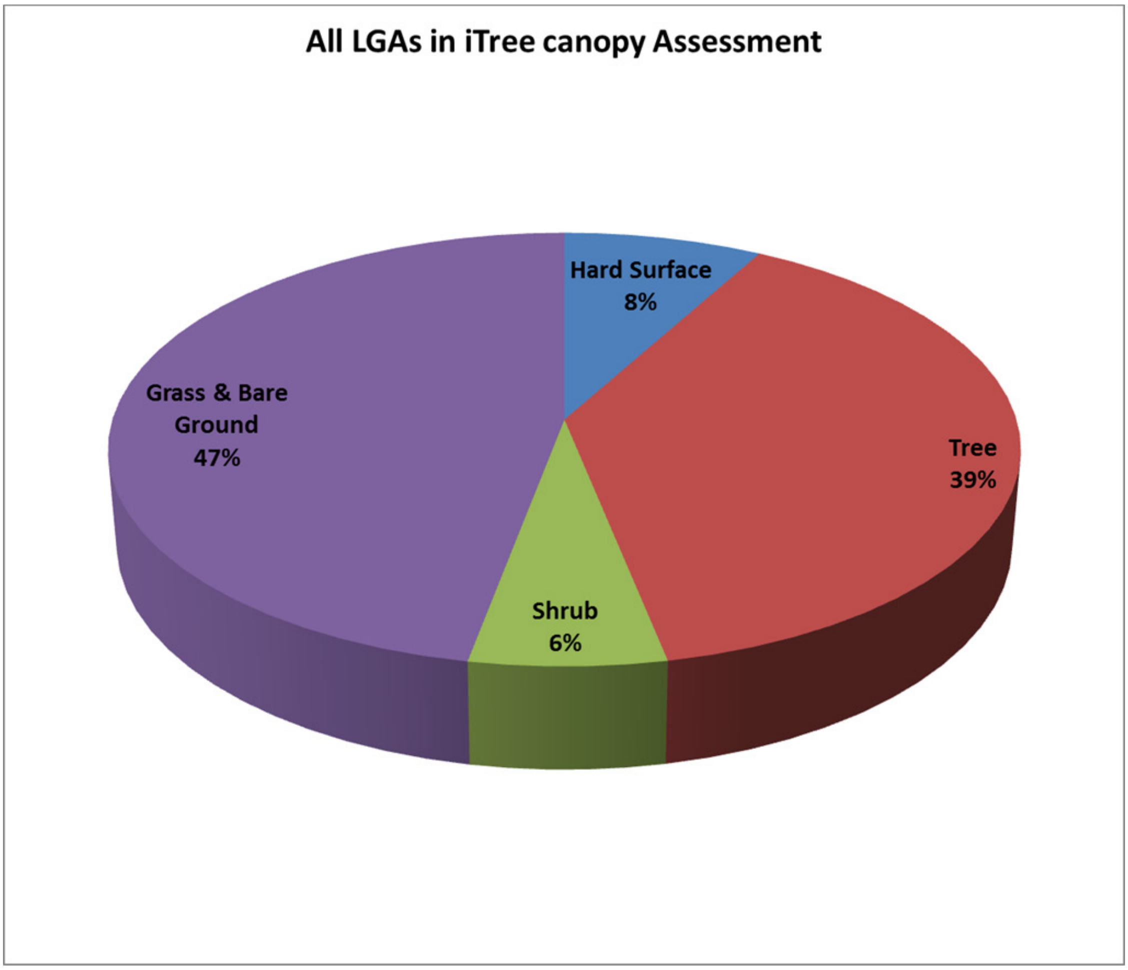
The i-Tree Canopy method applies a point-quadrat technique to project canopy. As such, it does not detect the nature of the ground surface that is obscured by tree canopy.

Finally, in some instances shadows can obscure the edges of trees or hide landscape features if they extend from large buildings. To account for this it is necessary to develop a standard approach to classifying points in shadow. For tree-edge shadows the user can consider whether the shadow appears to be inside or outside the radius of the tree crown. For extended building shadows the user looked to the surrounding context or classified the area as hard surface if the context could not be inferred for the shadow area.

3 RESULTS

The land area of the LGAs included in the iTree assessment totalled 62,185 km^2 or approximately 0.8% of the Australian land mass Although the proportion of the Australian land mass is small, it represents the most populous regions, with approximately 68% of the population of Australia live within these LGAs (ABS, 2012; ABS 2013) and therefore the areas most heavily impacted by the development of human settlements. Grass-bare ground was the most common land cover making up 47% of the area, followed by tree canopy at 39% (Figure 2). The other categories, hard surface and shrub, made up 8 and 6% of land cover respectively.

Figure 2 Percentage cover of all LGAs in the iTree canopy assessment



Urban areas included both single-LGA regional cities, such as Toowoomba and Newcastle, and capital cities comprised of multiple LGAs (for example Sydney and Melbourne). As a consequence the urban regions ranged widely in the absolute areas of each component of land cover (Figure 3). For example the tree canopy of Brisbane, a large urban area, was about 3,000 km^2 of tree canopy while Greater Darwin with a small urban footprint had only about 46km^2 of tree canopy. The relative proportions of each type of land cover followed the general pattern for the total area with tree canopy and grass-bare ground making up the greatest proportion of land cover in all areas (Figure 4).

However, hard surface varied considerably between locations and often substituted for the proportion of grass-bare ground particularly in heavily urbanized areas such as Sydney, Adelaide and Newcastle. With exception of Perth and Launceston, shrubs made up less than 10% of the land cover in all areas.

Figure 3: Areas of four categories of land cover for each of the urban regions included in the iTree Canopy assessment.

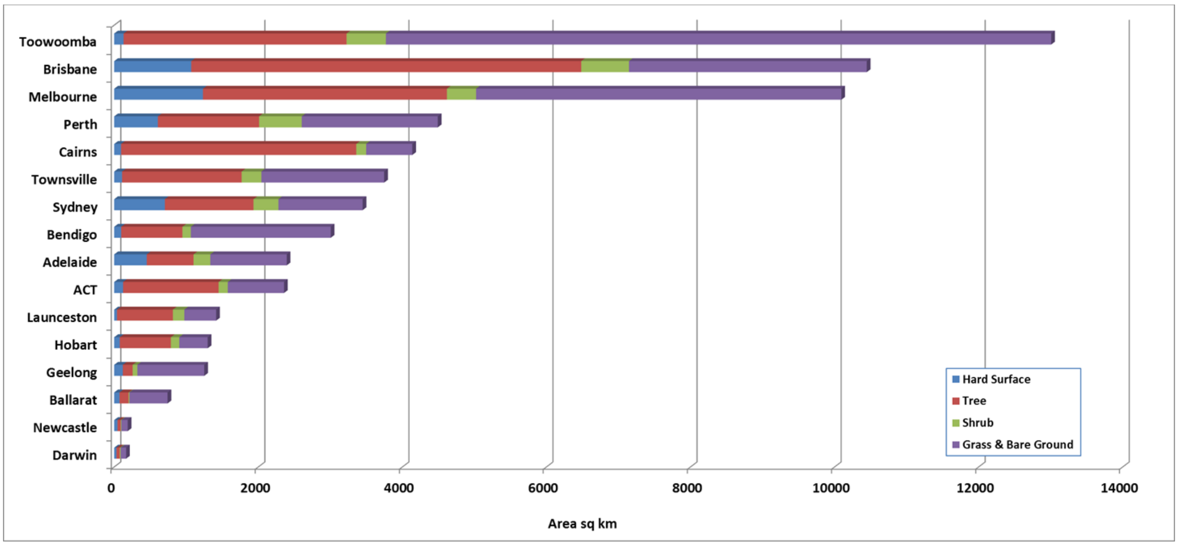


Figure 4: Relative proportions of four categories of land cover for each of the urban regions included in the iTree Canopy assessment.

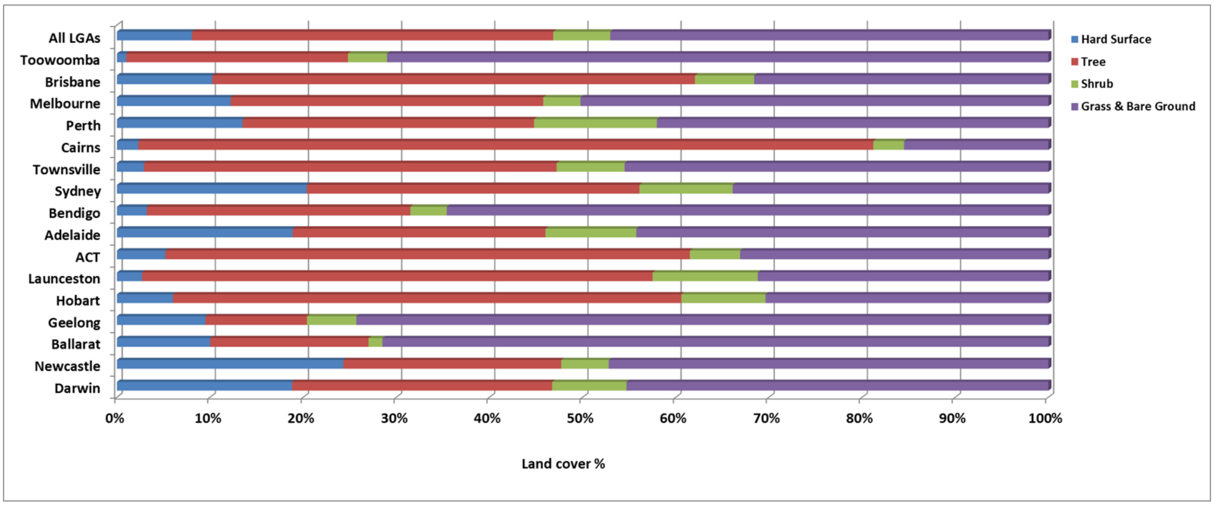
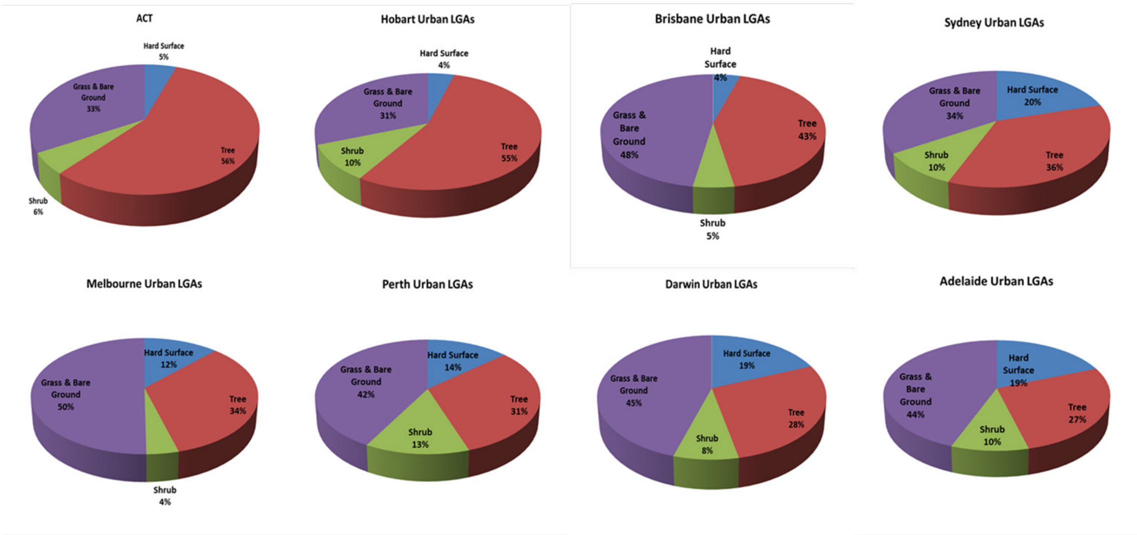


Figure 5 shows the relative proportions of each of the land cover types for the capital cities in the assessment. The proportion of tree cover ranged from the highest level of 56% for the ACT to the lowest of 27% in Adelaide. The proportion of grass-bare ground was highest in Melbourne; shrub cover was highest in Perth and hard surface marginally highest in Sydney at 20%.

Figure 5: Relative proportions of four categories of land cover for each capital city urban LGA included in the iTree canopy assessment. The cities are in rank order according to percentage tree canopy cover.



4 NEW SOUTH WALES

The iTree assessment for NSW included 39 LGAs, and accounts for 58% of the NSW population (ABS, 2012) in the Greater Sydney Region and the urban LGA centre in the regional city of Newcastle. Tree cover ranged from a high of 59% in Pittwater to a low of 12.1% in Botany (Figure 6).

Figure 6 Canopy cover (%) for selected New South Wales Local Government Areas

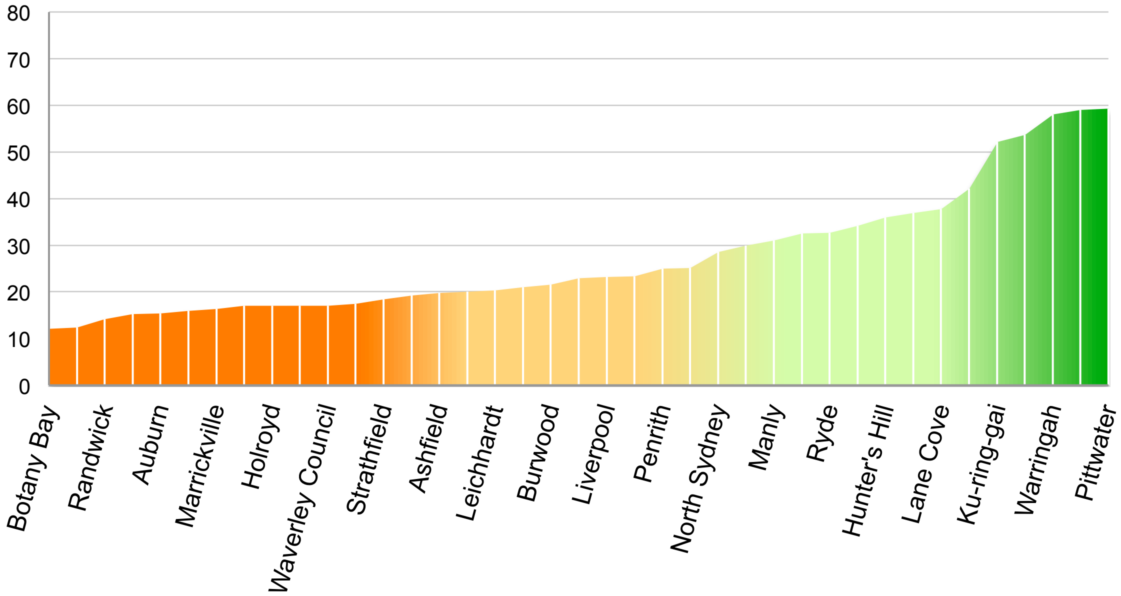


Figure 7 shows the geographical distribution of tree cover. Areas to the north of Greater Sydney, including Ku-ring-gai, The Hills, Warringah and Pittwater, had the highest proportions of tree cover in excess of 50%. These LGAs encompass large land area and therefore also had high absolute levels of tree cover (Table 4). In Hornsby Shire, for example, tree canopy cover exceeded 273km^2. In contrast, 15 urban and peri-urban LGAs had tree cover of less than 20%. These areas included a band of LGAs (shown in dark orange) from the coast to Fairfield and Blacktown in the west of the region. In particular, the inner city and densely populated LGAs of City of Sydney, Marrickville and Rockdale combined a low proportion of tree cover with a relatively high proportion (up to 69%) of hard surface. Although often smaller in total land area than LGAs to the north and south, together these LGAs with low tree cover share boundaries and form a large contiguous zone of low tree cover through the centre of the Sydney Basin. Areas to the west of Greater Sydney including Fairfield, Blacktown, Liverpool, Penrith and Camden showed the highest proportions of *grass-bare ground* (or potentially plantable area) and correspondingly lower proportions of *hard surface*.

Figure 7 Map of Canopy Cover (%) by selected New South Wales Local Government Areas

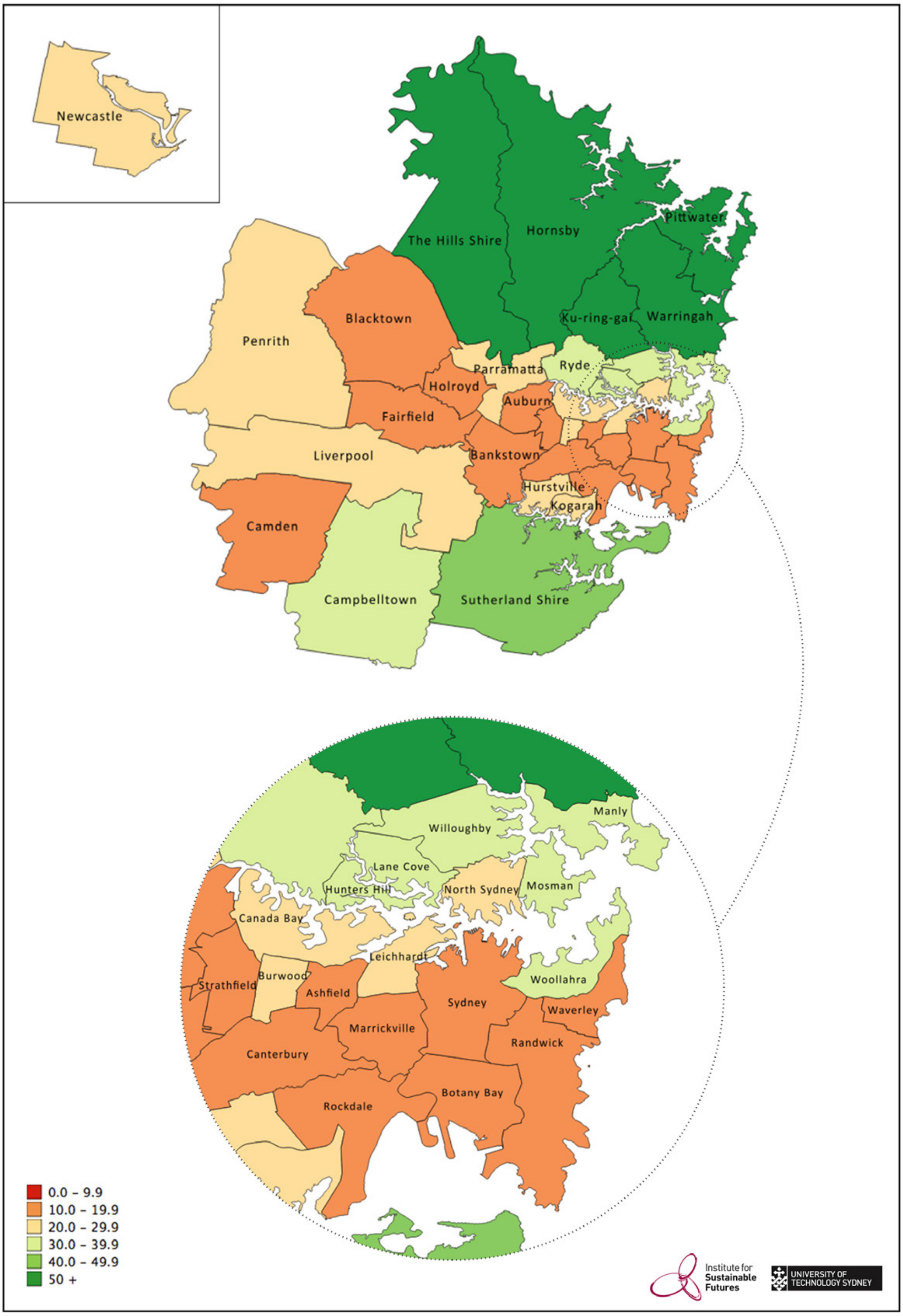


Table 4: New South Wales - tabulated i-Tree results sorted by canopy cover (%)

	Percent Cover (%)				*Land Cover (km^2)*			
LGA	**HS**	**T**	**S**	**G/BG**	**HS**	**T**	**S**	**G/BG**
Botany Bay, City of	55.4	12.1	2.8	29.7	12	2.63	0.61	6.46
Rockdale, City of	58.1	12.4	4.5	25	16.4	3.51	1.27	7.07
Randwick, City of	45.8	14.2	9.2	30.8	16.7	5.17	3.35	11.2
Sydney, City of	69.1	15.2	2.5	13.2	18.5	4.07	0.67	3.54
Auburn City	50.4	15.4	3.1	31.1	16.4	5.01	1.01	10.1
Fairfield, City of	35.8	16.0	4.6	43.6	36.4	16.3	4.69	44.4
Marrickville Council	63.4	16.3	4.9	15.4	10.5	2.7	0.81	2.55
Camden Council	9.7	17.0	3.4	69.9	19.6	34.3	6.86	141
Holroyd, City of	49.4	17.0	4.7	28.9	19.9	6.85	1.89	11.6
Bankstown, City of	50.3	17.1	3.7	28.9	38.7	13.2	2.85	22.3
Waverley Council	59.1	17.1	7.0	16.8	5.48	1.58	0.65	1.56
Canterbury, City of	54.5	17.5	5.2	22.8	18.3	5.89	1.75	7.67
Strathfield, Municipality of	52.8	18.4	3.5	25.3	7.36	2.56	0.49	3.53
Blacktown, City of	28.3	19.2	4.9	47.6	26.3	17.8	4.55	44.2
Ashfield, Municipality of	57.4	19.8	4.6	18.2	4.77	1.64	0.38	1.51
Canada Bay, City of	51.6	20	5.2	23.2	10.3	3.99	1.04	4.63
Leichhardt, Municipality of	59.8	20.3	4.7	15.2	6.32	2.15	0.5	1.61
Kogarah, City of	52.2	21	6.1	20.7	8.14	3.27	0.95	3.23
Burwood Council	56.7	21.5	4.6	17.2	4.05	1.54	0.33	1.23
Parramatta, City of	43.4	23	5.9	27.7	26.7	14.1	3.63	17
Liverpool, City of	16.3	23.2	9.4	51.1	49.9	71	28.8	156.5
Newcastle*, City of	24.3	23.4	5.1	47.2	45.5	43.8	9.55	88.4
Penrith, City of	15.3	25	5.7	54	62.1	101.4	23.1	219.1
Hurstville, City of	45.0	25.2	5.9	23.9	10.3	5.74	1.34	5.44
North Sydney Council	53.8	28.6	7.01	10.6	5.65	3.0	0.74	1.12
Woollahra, Municipality of	48.0	30	6.7	15.3	5.91	3.69	0.82	1.88
Manly Council	39.9	31.1	11.3	17.7	5.74	4.48	1.63	2.55
Mosman, Municipality of	47.8	32.5	9.7	10	4.15	2.82	0.84	0.87
Ryde, City of	38.6	32.7	7.1	21.6	15.7	13.3	2.88	8.76
Campbelltown, City of	12.0	34.2	15.3	38.5	37.6	107	47.9	120.5
Hunter's Hill, Municipality of	35.9	36.0	7.3	20.8	2.06	2.06	0.42	1.19
Willoughby, City of	42.6	37.0	7.0	13.4	3.7	3.21	0.61	1.16
Lane Cove, Municipality of	40.5	37.8	6.4	15.3	4.26	3.97	0.67	1.61
Sutherland Shire	13.3	42.1	21.5	23.1	44.5	140.8	71.9	77.3
Ku-ring-gai Council	21.5	52.1	9.2	17.2	18.4	44.6	7.88	14.7
The Hills Shire	11.6	53.7	10.8	23.8	46.7	215.6	43.4	95.7
Warringah Council	19.1	58.0	9.2	13.7	11	33.5	5.32	7.92
Hornsby Shire	8.4	59.0	12.6	20.0	38.9	273.4	58.4	92.7
Pittwater Council	14.5	59.3	11.1	15.1	13.1	53.7	10.1	13.7

5 VICTORIA

For Victoria, the iTree assessment included 34 LGAs, which account for 77% of the Victorian population (ABS, 2012), in the Greater Melbourne Region. Tree cover ranged from 77% in the Yarra Ranges to 3% in the City of Wyndham (Figure 8).

Figure 8 Canopy cover (%) for selected Victorian Local Government Areas

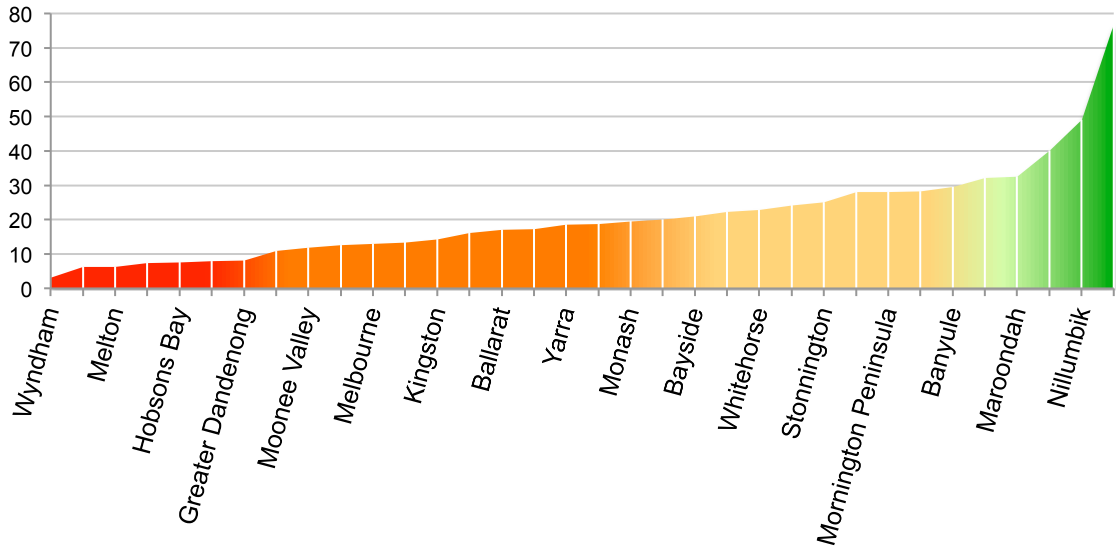


Figure 9 presents the geographic distribution of tree cover, with Manningham, Nilumbik and the Yarra Ranges in the northeast showing tree cover over 40%. The Yarra Ranges LGA contains a large portion of National Park, with a *tree cover* of 1,906 km^2 (Table 5). In contrast to the large areas of tree cover presented in the aforementioned regions, 19 of the LGAs in the Greater Metropolitan Area exhibit tree cover less that 20%, of which 7 LGAs have a *tree cover* of less than 10%. Wyndham, Melton and Hume, which present less than 10% tree cover have *grass-bare ground* cover of over 77%.

For the most part, the LGAs with less than 20% tree cover are located in the inner city and western regions of the Greater Melbourne Area. City of Port Philip, City of Yarra and City of Melbourne present the greatest proportion of *hard surface* and relatively lower proportions of *grass-bare ground* (Table 5).

Figure 9 Map of canopy cover (%) for selected Victorian Local Government Areas

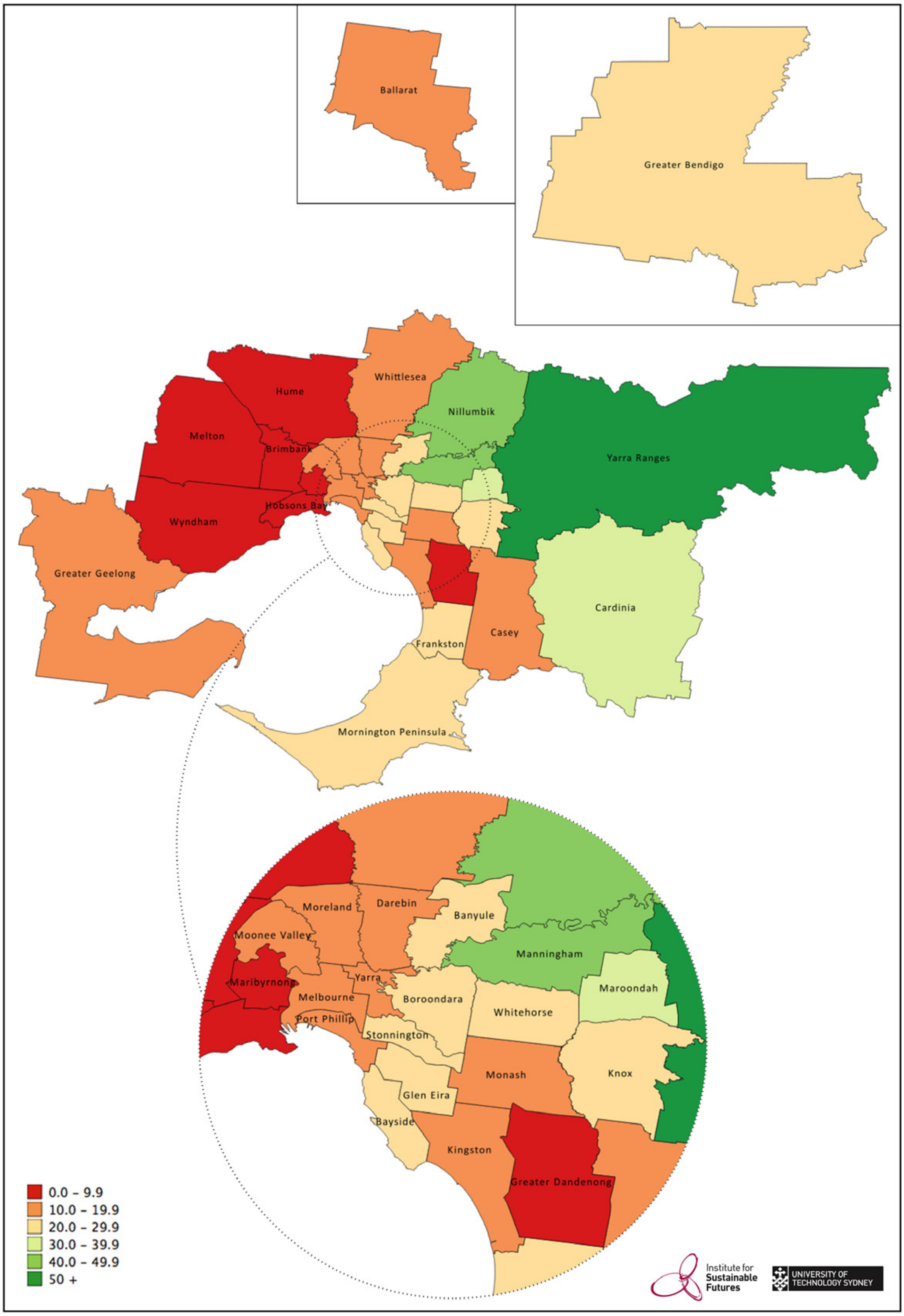


Table 5: Victoria – tabulated results sorted by Canopy Cover (%)

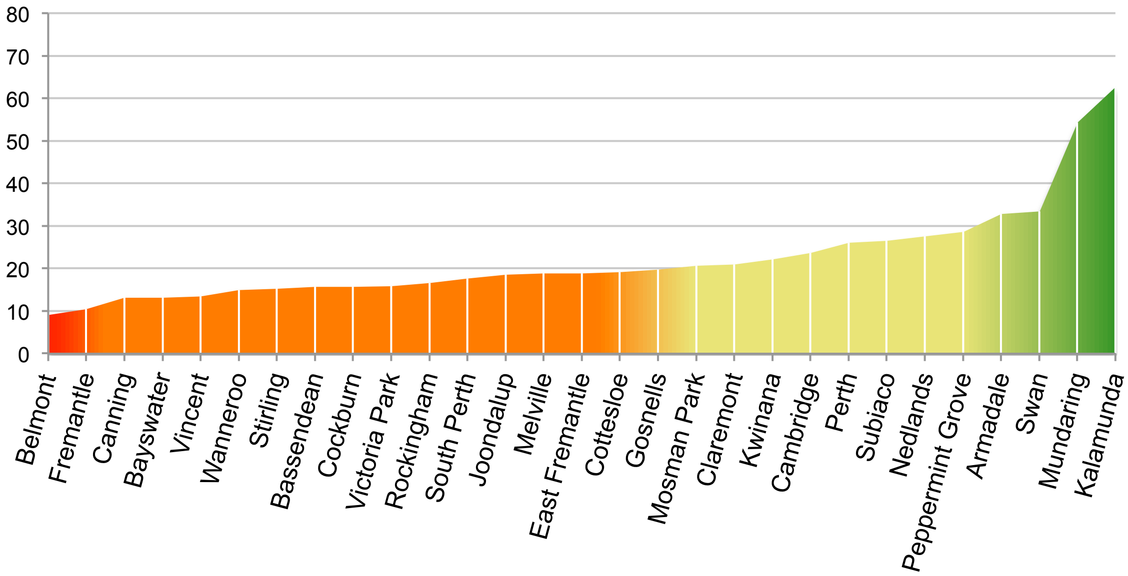
	Percent Cover (%)				*Land Cover (km2)*			
LGA	**HS**	**T**	**S**	**G/BG**	**HS**	**T**	**S**	**G/BG**
Wyndham, City of	12.9	3.1	2.7	81.3	70.0	16.8	14.7	441.5
Brimbank, City of	41.5	6.2	2.8	49.5	51.3	7.66	3.46	61.2
Melton, City of	6.0	6.3	2.7	85	31.7	33.3	14.3	449.2
Maribyrnong, City of	58.2	7.4	3.6	30.8	18.2	2.31	1.13	9.63
Hobsons Bay, City of	44.0	7.6	2.9	45.5	28.3	4.89	1.87	29.3
Hume, City of	11.7	7.9	3.1	77.3	59.1	39.9	15.6	390.1
Greater Dandenong, City of	39.4	8.2	2.6	49.8	51.1	10.6	3.37	64.6
Greater Geelong*, City of	9.5	10.9	5.3	74.3	118.7	136.2	66.2	928.7
Moonee Valley, City of	52.8	11.9	4.3	31	22.8	5.15	1.86	13.4
Casey, City of	19.9	12.6	7.2	60.3	81.6	51.7	29.5	247.3
Melbourne, City of	63.0	12.9	1.8	22.3	23.6	4.83	0.67	8.34
Moreland, City of	53.7	13.3	6.3	26.7	27.4	6.79	3.22	13.6
Kingston, City of	45.6	14.2	4.6	35.6	41.7	13.0	4.21	32.6
Port Phillip, City of	65.2	16.2	2.5	16.1	13.5	3.36	0.52	3.34
Ballarat*, City of	10.0	17.0	1.5	71.5	74.0	125.9	11.1	529.3
Darebin, City of	52.4	17.3	4.6	25.7	28.1	9.27	2.46	13.8
Yarra, City of	62.6	18.5	3.6	15.3	12.3	3.62	0.7	2.99
Whittlesea, City of	9.0	18.8	6.1	66.1	44.2	92.2	29.9	324.3
Monash, City of	49.3	19.4	6.3	25	40.2	15.8	5.14	20.4
Glen Eira, City of	58.5	20.0	6.5	15	22.7	7.75	2.52	5.81
Bayside, City of	52.2	21.0	7.7	19.1	19.5	7.83	2.87	7.12
Frankston, City of	30.1	22.3	6.2	41.4	39.1	28.9	8.05	53.7
Whitehorse, City of	47.8	22.9	7.49	21.9	30.8	14.7	4.82	14.1
Knox, City of	36.5	24.2	6.2	33.1	41.6	27.6	7.07	37.7
Stonnington, City of	57.2	25.0	6.8	11	14.7	6.42	1.75	2.83
Boroondara, City of	48.4	28.1	8.0	15.5	29.2	16.9	4.82	9.34
Mornington Peninsula, Shire of	9.7	28.1	6.9	55.3	70.3	203.8	50.0	401
Greater Bendigo*, City of	3.2	28.3	3.9	64.6	96.2	850.6	117.2	1941
Banyule, City of	38.3	29.6	6	26.1	24	18.5	3.76	16.4
Cardinia, Shire of	4.2	32.2	3.1	60.5	53.9	413.4	39.8	776.7
Maroondah, City of	40.2	32.5	5.6	21.7	24.7	20	3.44	13.3
Manningham, City of	23.3	40.1	7.6	29	26.5	45.5	8.63	32.9
Nillumbik, Shire of	6.5	49.1	5.5	38.9	28.2	212.6	23.8	168.5
Yarra Ranges, Shire of	1.7	77.2	1.8	19.3	42.0	1906	44.5	477.2

**Differentiates Local Government Areas located beyond the Greater Capital City boundary*

6 WESTERN AUSTRALIA

In Western Australia, 29 Local Government Areas, which account for 64% of the WA population (ABS, 2012), were included in the iTree analysis. The proportion of tree cover in the selected areas ranged from 62% in Kalamunda to 9% in Belmont (Figure 10).

Figure 10 Canopy cover (%) for selected West Australian Local Government Areas



While the City of Belmont was the only LGA in the Greater Perth region to present with a tree cover less than 10%, 16 of the 29 areas had a tree cover less than 20%.

The eastern fringe of metropolitan Perth, including the LGAs of Armadale, Swan, Mundaring and Kalamunda, exhibit the highest proportions of tree cover of more than 30% (Figure 11). Portions of these areas include state forest and national parks. The coastline on the western side of the city presents a corridor of relatively higher tree cover between 10-20%. Vincent, Fremantle, East Fremantle and Subiaco all have *hard surface* proportions of over 50% and *grass-bare ground* areas under 20%. These areas are more densely populated, and border the coast. Belmont, Canning, Bayswater, Stirling and Joondaup also present *hard surface* proportions of over 50%, but with *grass-bare* ground proportions of over 25%.

Local government areas of Wanneroo, Rockingham and Gosnells, were areas of relatively low tree cover with the highest proportions of *grass-bare ground* cover (Table 6).

Figure 11 Map of canopy cover (%) for selected West Australian Local Government Areas

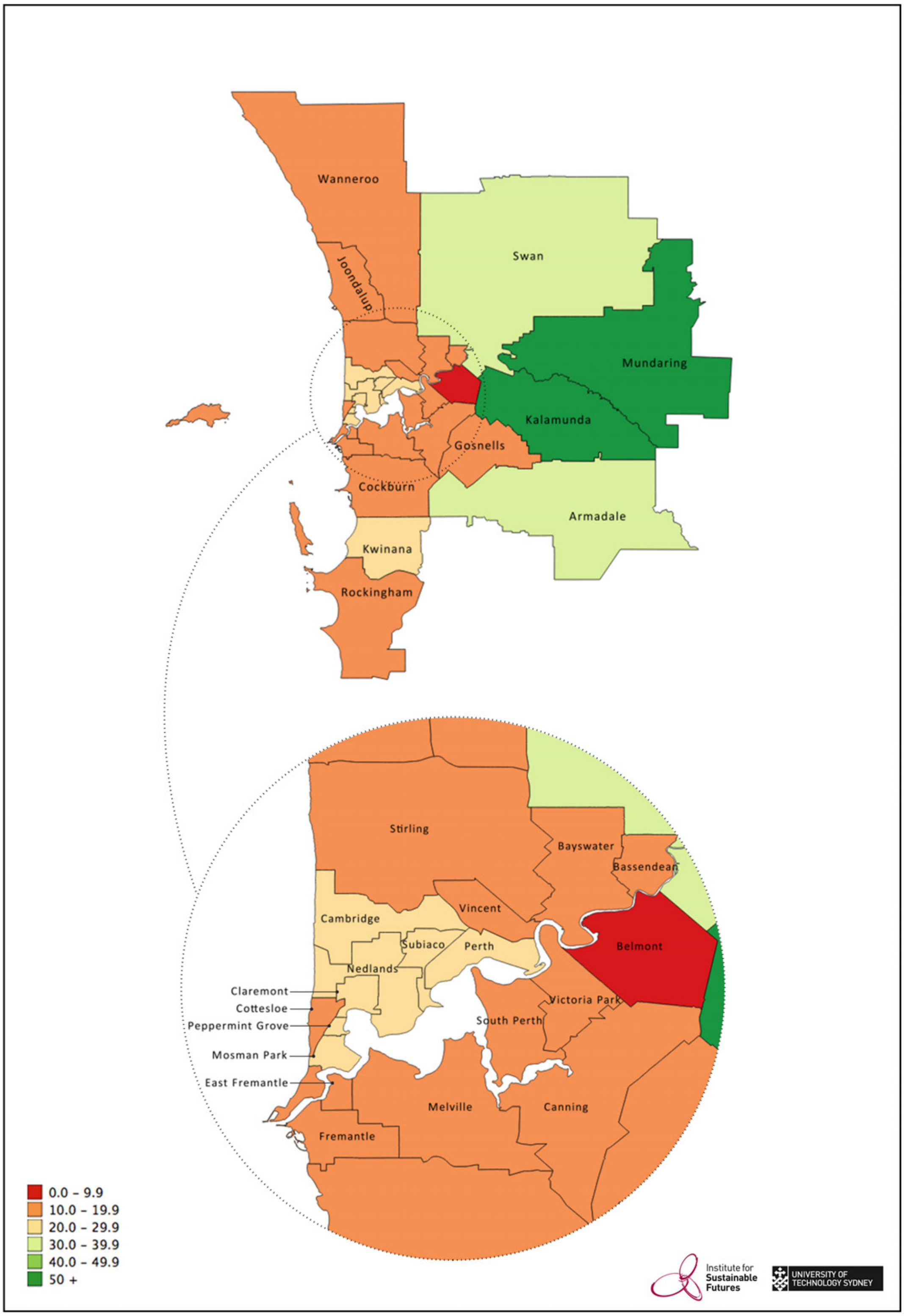


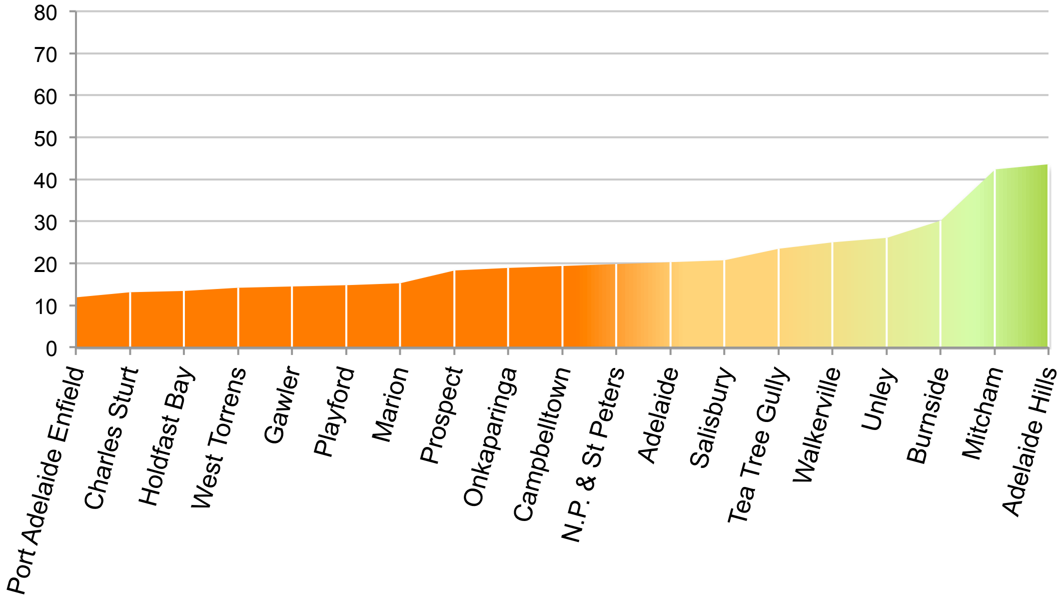
Table 6: Western Australia - tabulated results (%) sorted by canopy cover

	Percent Cover (%)				*Land Cover (km2)*			
LGA	**HS**	**T**	**S**	**G/BG**	**HS**	**T**	**S**	**G/BG**
Belmont, City of	50.6	9.1	9.5	30.8	20.1	3.62	3.78	12.3
Fremantle, City of	65.1	10.4	6.1	18.4	12.4	1.98	1.16	3.51
Canning, City of	53.1	13.1	7.2	26.6	34.6	8.53	4.69	17.3
Bayswater, City of	53.5	13.2	8	25.3	17.6	4.34	2.63	8.32
Vincent, City of	65.9	13.4	4.1	16.6	7.52	1.53	0.47	1.89
Wanneroo, City of	7.9	15	12.3	64.8	54.3	103.1	84.5	445.3
Stirling, City of	52.9	15.2	4.8	27.1	55.5	16	5.05	28.5
Bassendean, Town of	45.8	15.7	5.2	33.3	4.75	1.63	0.54	3.45
Cockburn, City of	26.5	15.7	23.4	34.4	44.6	26.4	39.4	57.9
Victoria Park, Town of	51.0	15.8	4.2	29.0	9.17	2.84	0.76	5.22
Rockingham, City of	17.7	16.6	17.7	48	45.6	42.8	45.6	123.7
South Perth, City of	49.6	17.7	4.8	27.9	9.86	3.52	0.95	5.54
Joondalup, City of	50.8	18.5	5.5	25.2	50.4	18.4	5.46	25
Melville, City of	49.1	18.8	5.1	27.0	26	9.96	2.7	14.3
East Fremantle, Town of	56.9	18.9	4.6	19.6	1.79	0.59	0.14	0.62
Cottesloe, Town of	49.9	19.2	4.9	26.0	1.93	0.74	0.19	1.01
Gosnells, City of	24.2	19.7	15.3	40.8	30.9	25.1	19.5	52.1
Mosman Park, Town of	48.7	20.7	6.9	23.7	2.12	0.9	0.3	1.03
Claremont, Town of	54.2	20.9	4.6	20.3	2.69	1.04	0.23	1.01
Kwinana, City of	18.8	22.2	16.7	42.2	22.7	26.7	20.1	50.8
Cambridge, Town of	35.9	23.6	9.6	30.9	7.92	5.21	2.12	6.82
Perth, City of	46.8	26.1	3.3	23.8	5.64	3.15	0.4	2.87
Subiaco, City of	56.4	26.5	3.5	13.6	3.95	1.85	0.24	0.95
Nedlands, City of	34.3	27.6	5.9	32.2	6.86	5.52	1.18	6.44
Peppermint Grove, Shire of	48.2	28.6	5.2	18	0.52	0.31	0.06	0.19
Armadale, City of	6.3	32.8	36.2	24.7	35.4	184.2	203.3	138.7
Swan, City of	4.4	33.5	10.6	51.5	46	350.5	110.9	538.9
Mundaring, Shire of	3.6	54.4	3.1	38.9	23.2	351	20	251
Kalamunda, Shire of	6.7	62.8	4.8	25.7	21.8	204.2	15.6	83.6

7 SOUTH AUSTRALIA

In South Australia, 19 LGAs, which account for 73% of the SA population (ABS, 2012), were included in the iTree analysis. The proportion of tree cover for the selected LGAs ranged from 43.7% in Adelaide Hills to 11.9% in Port Adelaide Enfield (Figure 12).

Figure 12 Canopy cover (%) for selected South Australian Local Government Areas



The two LGAs with the highest tree cover, Adelaide hills and Mitcham, have conservation areas in their boundaries.

None of the LGAs analysed in this study present a tree cover less the 10%, however 11 of the 19 fall within the 10-20% range. These suburbs are distributed along the coast and around the city centre (Figure 13). The areas of Holdfast, Prospect and Norwood, Payneham and St Peters all have relatively high *hard surface* proportions of over 60% with *grass–bare ground* cover of under 20% (Table 7).

In contrast, Gawler, Playford and Onkaparinga, which have less than 20% tree cover present with proportions of *grass-bare ground* of over 50% and *hard surfaces* of less than 20% (Table 7).

Figure 13 Map of canopy cover (%) for selected South Australian Local Government Areas

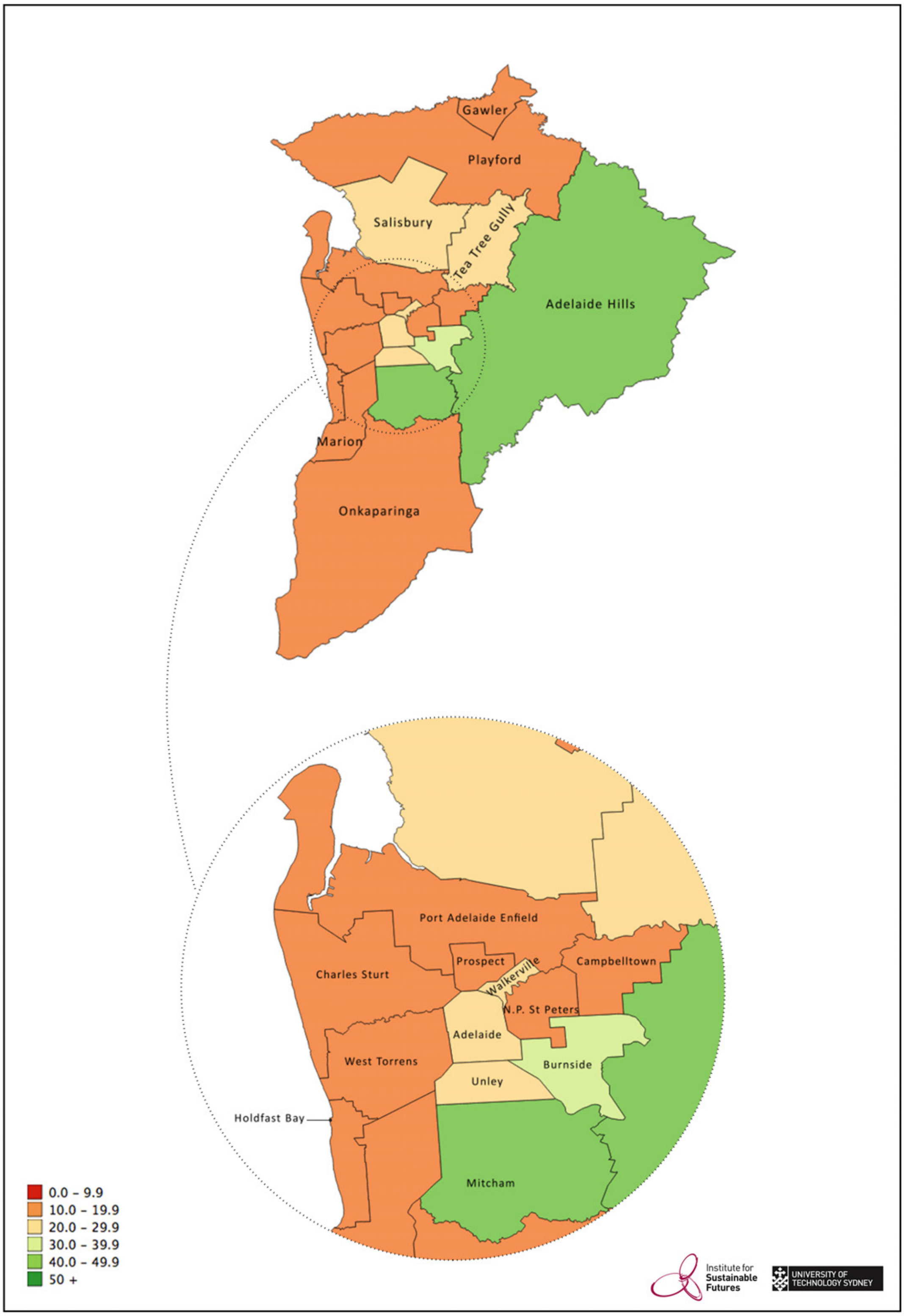
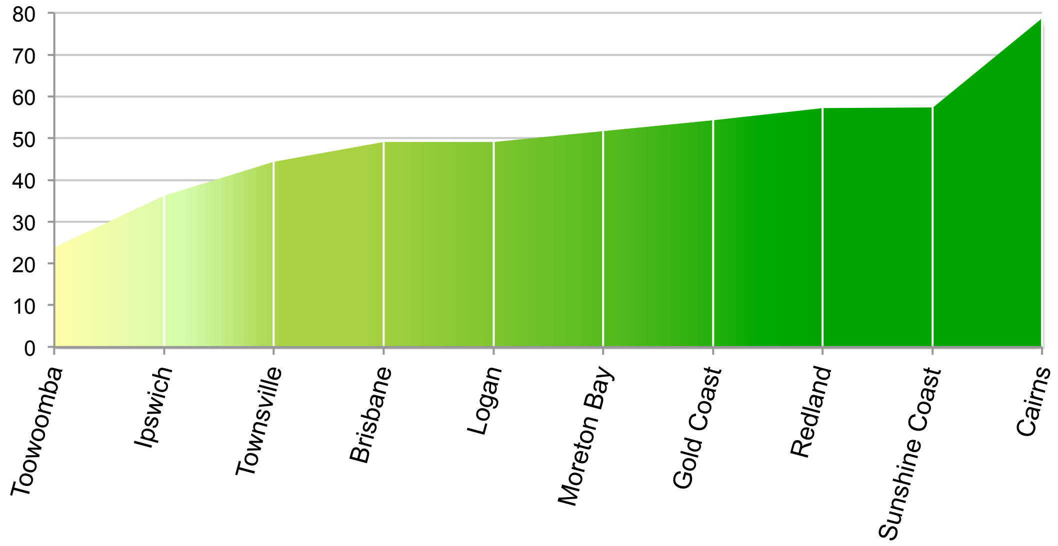


Table 7: South Australia - tabulated results sorted by canopy cover (%)

	Percent Cover (%)				*Land Cover (km2)*			
LGA	**HS**	**T**	**S**	**G/BG**	**HS**	**T**	**S**	**G/BG**
Port Adelaide Enfield, City of	55.1	11.9	2.6	30.4	50.7	10.9	2.39	28
Charles Sturt, City of	54.8	13.2	4.5	27.5	30.1	7.25	2.47	15.1
Holdfast Bay, City of	65.8	13.4	3.5	17.3	9.07	1.85	0.48	2.38
West Torrens, City of	50.6	14.2	3.7	31.5	18.8	5.27	1.37	11.7
Gawler, Town of	18.4	14.6	4.2	62.8	7.58	6.01	1.73	25.9
Playford, City of	16.5	14.8	7.7	61	57	51.2	26.6	210.9
Marion, City of	40.6	15.3	5.1	39	22.6	8.53	2.84	21.7
Prospect, City of	61.1	18.4	3.7	16.8	4.77	1.44	0.29	1.31
Onkaparinga, City of	11.2	18.9	15.2	54.7	58.2	98.1	78.9	284.1
Campbelltown, City of	46.3	19.4	8.1	26.2	11.3	4.73	1.98	6.39
Norwood Payneham & St Peters, City of	61.3	19.9	5.3	13.5	9.28	3.01	0.8	2.04
Adelaide, City of	46.5	20.3	1.3	31.9	7.26	3.17	0.2	4.98
Salisbury, City of	37.0	20.8	3.5	38.7	58.6	33	5.54	61.3
Tea Tree Gully, City of	29.5	23.5	6.5	40.5	28.2	22.4	6.2	38.7
Walkerville, Town of	57.3	25.0	5.6	12.1	2.03	0.88	0.2	0.43
Unley, City of	57.0	26.1	5.8	11.1	8.15	3.73	0.83	1.59
Burnside, City of	34.2	30.2	7.3	28.3	9.43	8.33	2.01	7.81
Mitcham, City of	23.6	42.4	7.11	26.8	17.9	32.1	5.38	20.3
Adelaide Hills Council	5.1	43.7	11.7	39.5	40.6	348	93.2	314.6

8 QUEENSLAND

Figure 14 Canopy cover (%) for selected Queensland Local Government Areas



In Queensland,10 LGAs, which account for 74% of the Qld population (ABS, 2012), were included in the iTree analysis. However, due to the large size of the selected LGAs in Brisbane, the region was analysed at two levels; LGA and Statistical Subdivision (SSD). An analysis at an SSD level allowed finer scale differences in land cover to be measured for the greater Brisbane region.

At an LGA level, tree cover ranged from 23.8% in Toowoomba to 78.9% in Cairns(Table 8). The SSDs in Brisbane ranged from 16.3% tree cover in Inner Brisbane to 64.9% in Gold Coast SD Bal. The geographic distribution of tree cover at an SSD level (Figure 15) is reflective of population density levels of inner Brisbane, with increasing levels of tree cover outside of the urban centre.

Toowoomba and Ipswich LGAs present with *grass-bare ground* proportions of over 50% and *hard surface* proportions of less than 6%. Toowoomba offers particularly high proportions of *grass-bare ground* of 71%, representing 9,235km^2 of land.

Examining the hard surface proportions is more useful at an SSD level for the greater Brisbane area. Along with presenting the lowest level of tree cover in the region, Inner Brisbane and Gold Coast show the highest proportions of *hard surface* of over 50% and *grass-bare ground* coverage of less than 25%. These ratios were similar in the surrounding areas of Southern Inner Brisbane and Northern Inner Brisbane.

At a SSD level, *grass-bare ground* proportions were the highest in Caboolture and Logan with more than 30%, compared to *hard surface* proportions of less than 10%.

Figure 15 Map of canopy cover (%) for selected Queensland Local Government Areas

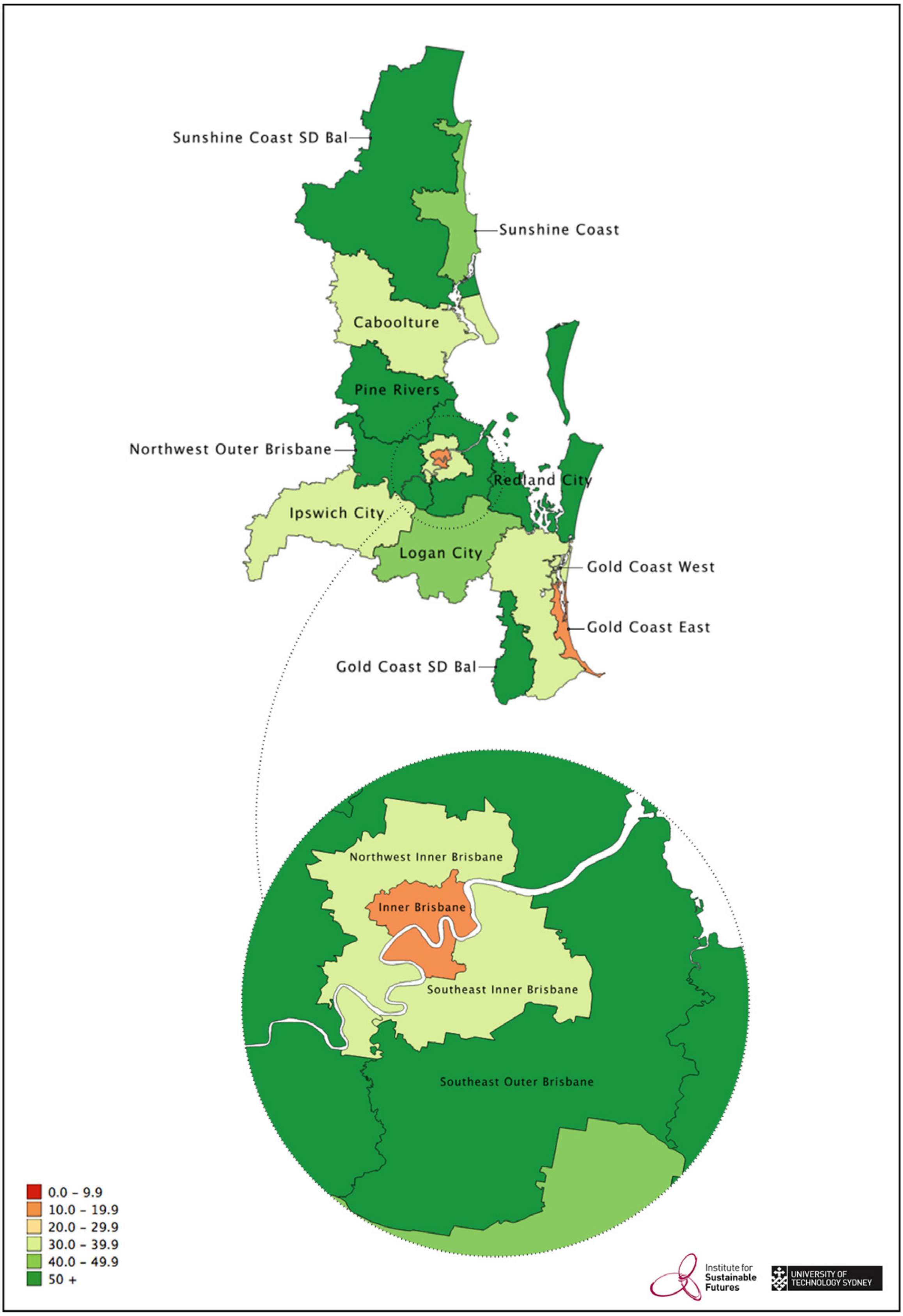


Table 8: Queensland - tabulated results (%) sorted by canopy cover

	Percent Cover (%)				Land Cover (km2)			
LGA	**HS**	**T**	**S**	**G/BG**	**HS**	**T**	**S**	**G/BG**
Toowoomba Regional Council	1.0	23.8	4.2	71	130.1	3095.8	546.3	9235
Ipswich, City of	5.2	36.2	3.7	54.9	56.8	395.5	40.4	599.9
Townsville City Council	2.9	44.3	7.3	45.5	108.7	1659.9	273.5	1704
Brisbane, City of	21.3	49.1	5.4	24.2	286.1	659.6	72.5	325.1
Logan City	9.9	49.1	6.1	34.9	95.2	472.2	58.7	335.7
Moreton Bay Region	9.2	51.7	6.1	33.0	187.8	1055.4	124.5	673.6
Gold Coast City	15.5	54.3	8.6	21.6	207.2	725.8	115	288.7
Redland City	7.6	57.2	17.1	18.1	40.9	307.9	92.1	97.4
Sunshine Coast	6.2	57.4	5.1	31.3	194.3	1798.5	159.8	980.7
Cairns Regional Council	2.3	78.9	3.3	15.5	95.2	3265.1	136.6	641.4

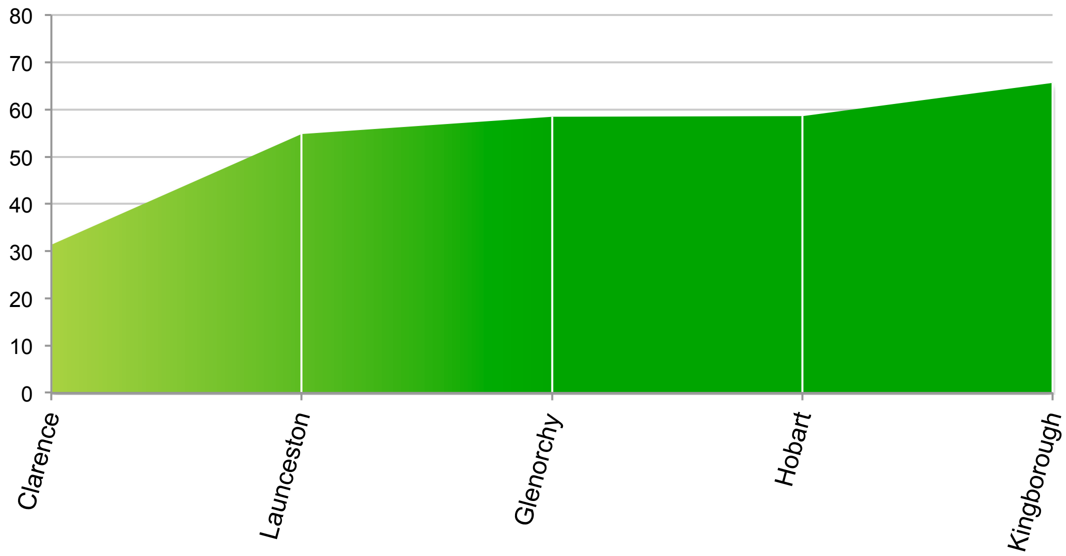
SSD*	HS	T	S	G/BG	HS	T	S	G/BG
Inner Brisbane	59.7	16.3	3.9	20.1	16.9	4.61	1.1	5.69
Gold Coast East	50.5	17.2	9.8	22.5	52.7	17.9	10.2	23.5
Southeast Inner Brisbane	43.9	30.6	3.6	21.9	32.8	22.9	2.69	16.4
Northwest Inner Brisbane	41.3	34.5	5.0	19.2	35.9	30	4.35	16.7
Gold Coast West	17.2	36.9	20.5	25.4	158	338.9	188.3	233.3
Caboolture	8.8	39.1	17.9	34.2	108	479.7	219.6	419.6
Sunshine Coast	20.5	43.0	14.1	22.4	95	199.4	65.4	103.8
Logan City	9.9	49.1	6.1	34.9	95.2	472.2	58.7	335.7
Northwest Outer Brisbane	17.9	50.1	8.3	23.7	118	330.4	54.7	156.3
Southeast Outer Brisbane	22.4	54.3	6.4	16.9	110.6	268.2	31.6	83.5
Redland	7.6	57.2	17.1	18.1	40.9	307.9	92.1	97.4
Sunshine Coast SD Bal	3.6	58.0	9.0	29.4	96.1	1548.4	240.3	784.9
Pine Rivers	13.0	59.4	3.8	23.8	100.9	461.1	29.5	184.8
Gold Coast SD Bal	5.3	64.9	13.7	16.1	16.6	203.7	43.0	50.5

**Differentiates Local Government Areas located beyond the Greater Capital City boundary*

9 TASMANIA

In Tasmania, 5 LGAs, which count for 48% of the population of Tasmania (ABS, 2012) were included in the analysis with a tree cover ranging from 65.7% in Kingborough to 31.4% in Clarence (Figure 16).

Figure 16 Canopy cover (%) for selected Tasmanian Local Government Areas



Of the 5 LGAs included in the analysis, 4 of these presented tree cover of more than 40%. *Hard surface* proportions were very low in all LGAs, all presenting a cover of under 20% (Figure 17).

The City of Clarence shows the highest proportion of *grass-bare ground,* comprising of 50.1% of the area (Table 9).

Figure 17 Map of canopy cover (%) for selected Tasmanian Local Government Areas

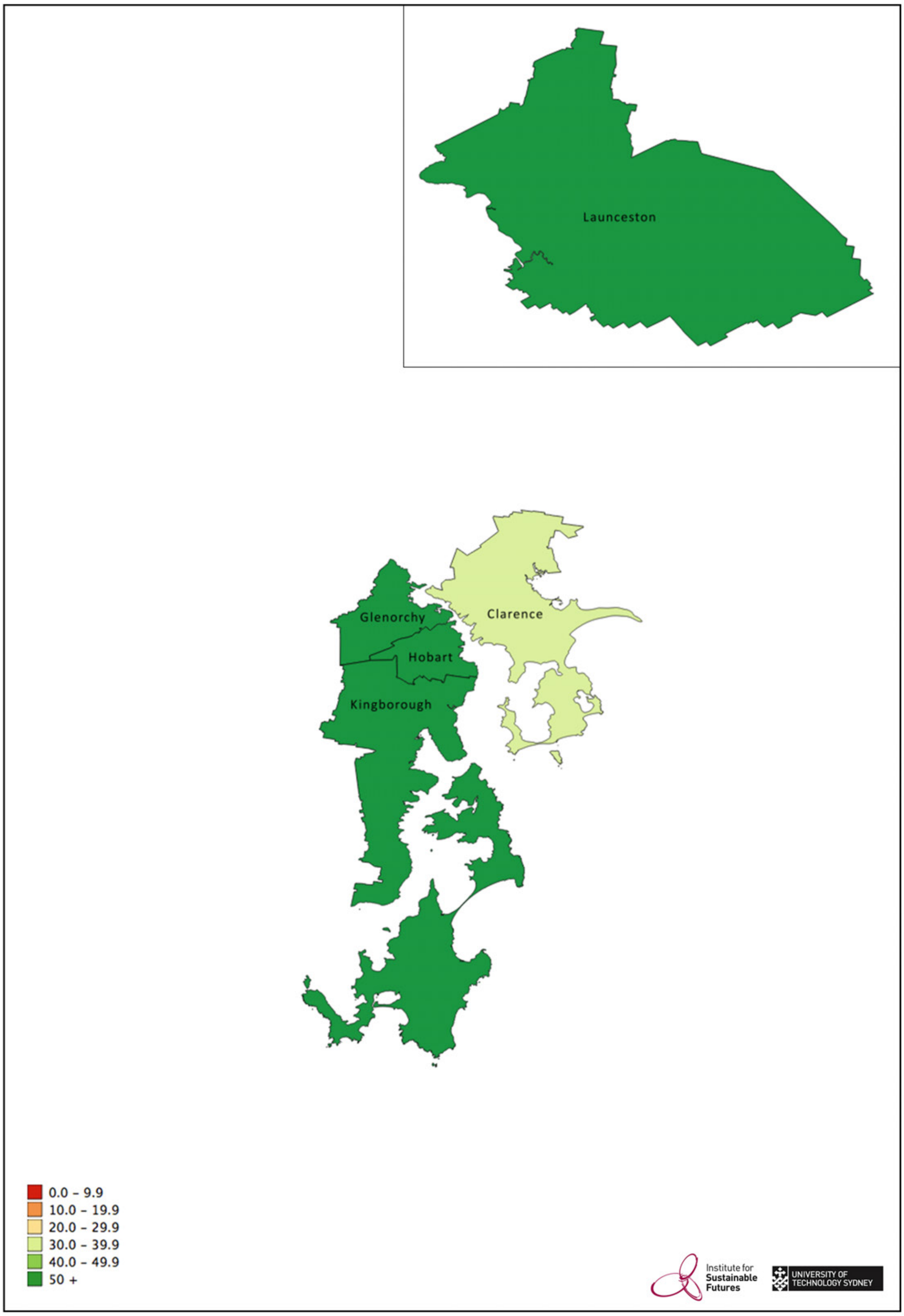


Table 9: Tasmania - tabulated results (%) sorted by canopy cover

	Percent Cover (%)				*Land Cover (km2)*			
LGA	**HS**	**T**	**S**	**G/BG**	**HS**	**T**	**S**	**G/BG**
Clarence, City of	8.5	31.4	10.0	50.1	32.1	118.7	37.8	189.5
Launceston*, City of	2.7	54.8	11.3	31.2	38.2	775.3	159.9	441.4
Glenorchy, City of	13.8	58.5	4.1	23.6	16.7	70.9	4.97	28.6
Hobart, City of	18.7	58.6	8.5	14.2	14.6	45.7	6.63	11.1
Kingborough Council	2.0	65.7	9.4	22.9	14.4	473.3	67.7	165

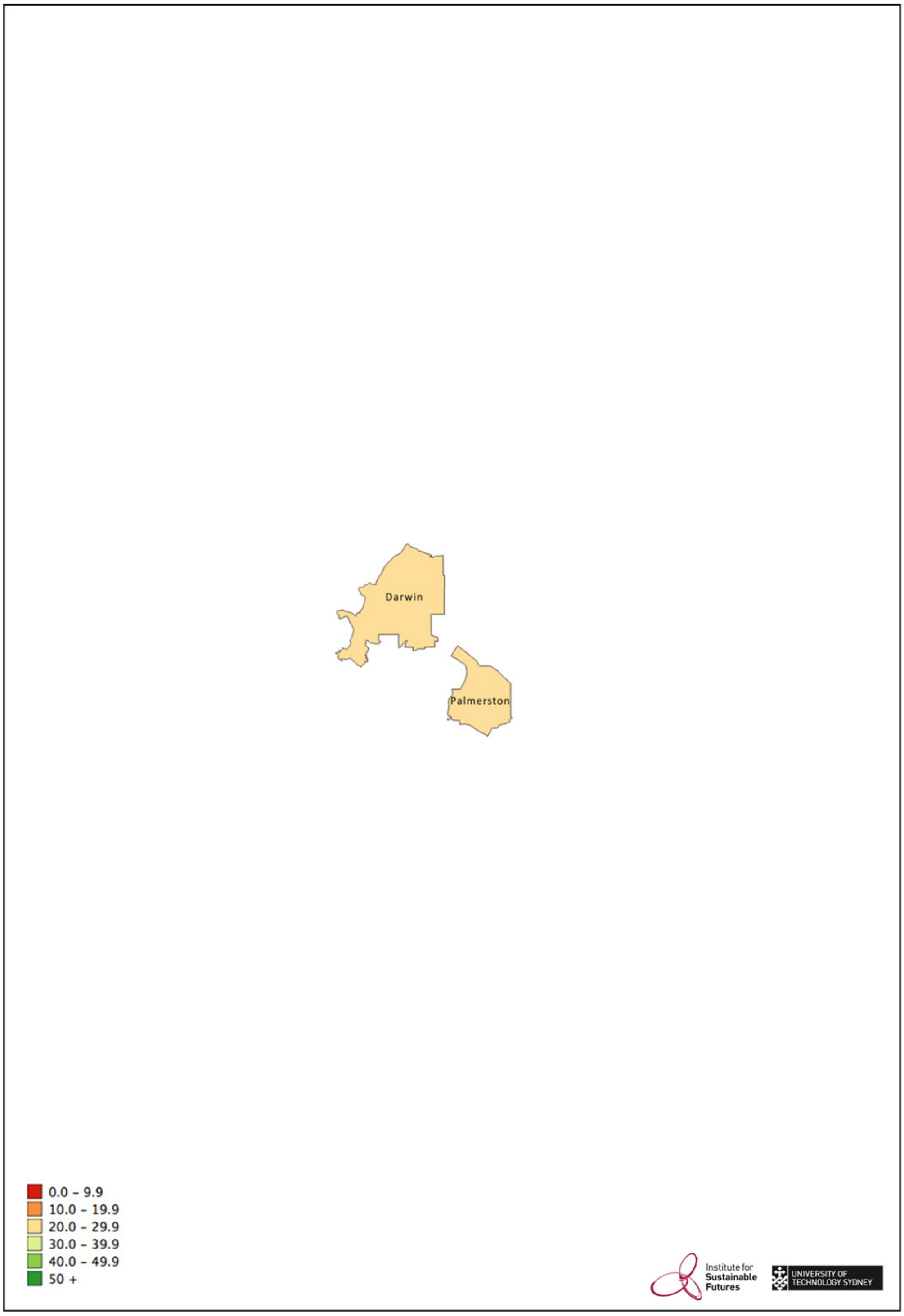
10 NORTHERN TERRITORY

The two LGAs analysed in the Northern Territory, accounting for 45% of the NT population (ABS 2012), centred within Greater Darwin, returned estimates of between 20-30% tree cover (Figure 18). Both areas show high proportions of *grass-bare ground* (over 40%) with *hard surface* proportions of under 20% (Table 10).

Table 10 Northern Territory - tabulated results (%) sorted by canopy cover

	Percent Cover (%)				*Land Cover (km2)*			
LGA	**HS**	**T**	**S**	**G/BG**	**HS**	**T**	**S**	**G/BG**
Darwin, City of	20	27.7	6.31	45.9	22.5	31.1	7.08	51.5
Palmerston, City of	16.1	28.4	11.5	44	8.53	15	6.09	23.3

Figure 18 Map of canopy cover (%) by selected Northern Territory Local Government Areas



11 ACT

For the Australian Capital Territory, the LGA tree cover proportion was 56.3%

Table 11: ACT - Tabulated results (%) sorted by canopy cover

	Percent Cover (%)				*Land Cover (km2)*			
LGA	**HS**	**T**	**S**	**G/BG**	**HS**	**T**	**S**	**G/BG**
ACT	5.2	56.3	5.4	33.1	122.6	1326.9	127.3	780.1

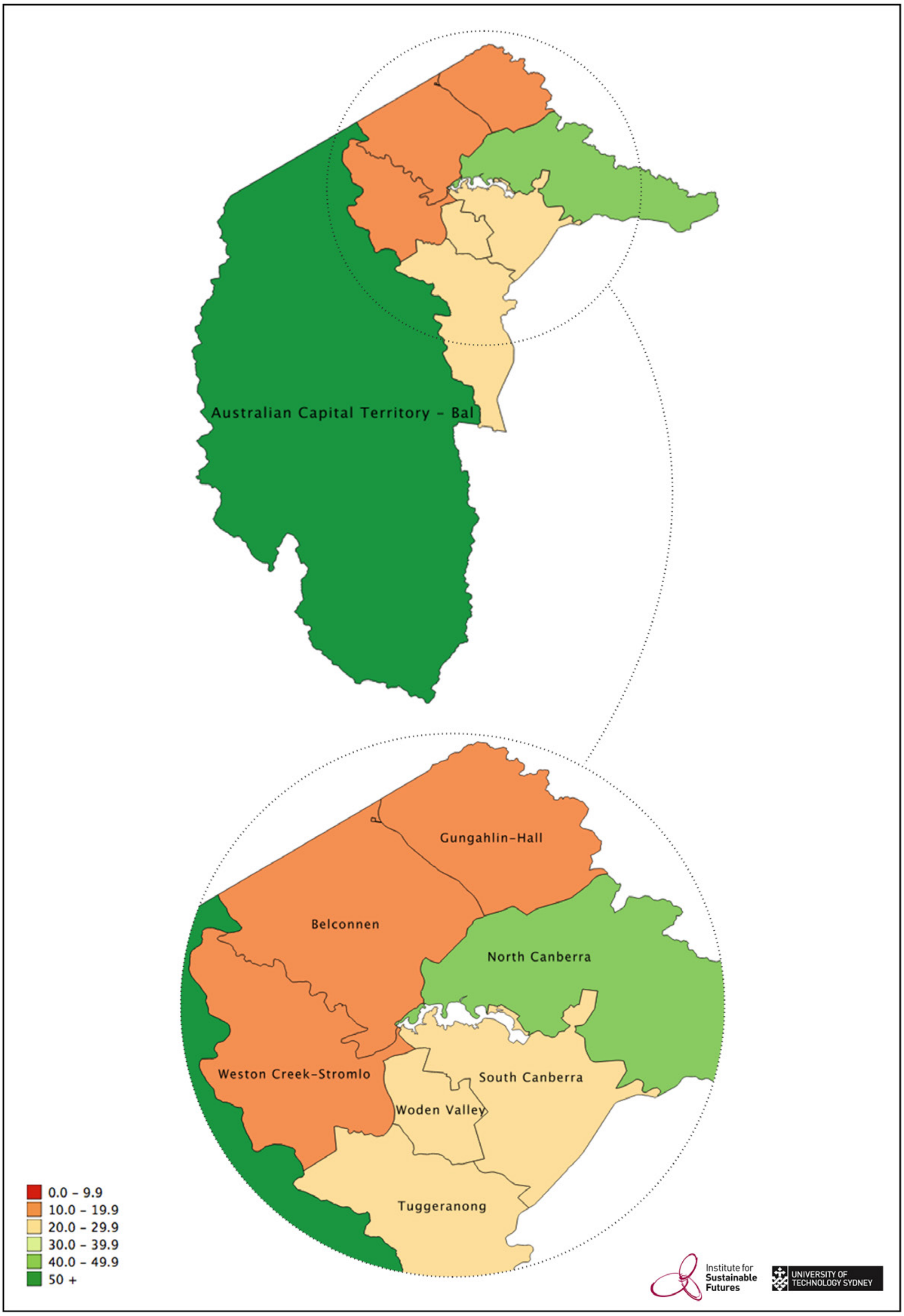
	Percent Cover (%)				*Land Cover (km2)*			
SSD*	**HS**	**T**	**S**	**G/BG**	**HS**	**T**	**S**	**G/BG**
Weston Creek-Stromlo	8.8	10.3	8.4	72.5	9.2	10.8	8.78	75.8
Belconnen	18.5	14.7	5	61.8	24.2	19.3	6.55	80.9
Gungahlin-Hall	16.6	15.8	2.9	64.7	15.1	14.3	2.63	58.7
South Canberra	14.9	20.2	6.4	58.5	13.1	17.7	5.61	51.3
Tuggeranong	14.6	21.3	5.9	58.2	23.4	34.1	9.44	93.1
Woden Valley	30.9	28	6.7	34.4	8.86	8.03	1.92	9.86
North Canberra	6.8	49.8	1.7	41.7	14.1	103.1	3.52	86.3
Australian Capital Territory - Bal	0.8	75.5	4.6	19.1	12.4	1168.3	71.2	295.6

However, as with Queensland, to offer more useful analysis of the variation within the ACT, the region has been analysed at a SSD level. At this scale, tree cover ranged from 75.5% in the ACT BAL to 10.3% in Weston Creek-Stromlo.

Aside from Woden Valley, which presented with *hard surface* proportions of 30.9%, the remaining 7 SSDs had relatively low *hard surface* proportions of less than 20%.

Each of the SSDs in the ACT presented with greater proportions of *grass-bare ground* than *hard surfaces*, with the greatest proportion of *grass-bare ground* present in Weston Creek-Stromlo with 72.5%.

Figure 19 Map of canopy cover (%) for ACT Local Government Area



12 DISCUSSION

This research has been commissioned to provide a rapid, low cost land cover estimate for selected urban and regional LGAs across Australia. Distinguishing between 4 main categories (tree, shrub, grassland/bare ground and hard surfaces) gives local councils a snapshot indication of their current land cover composition. This analysis is the first step in assisting LGAs to identify current levels of tree cover as well as opportunities that will work within the unique urban and natural geographies of each local area. This mapping is not designed to replace detailed analysis of vegetation conducted using LiDAR or other research tools. In addition, we acknowledge that variations in tree cover occur as part of the biophysical aspects of the landscape, such as native vegetation structure, soil fertility and texture, drainage patterns and multiple aspects of climate. This project was conducted as part of a process to catalyse social change in Australia's urban areas.

The information generated from i-Tree analysis of Australia's urban LGAs has potential use at two scales. At a regional scale, the mapping of tree canopy reveals patterns of land cover that occur across LGA boundaries and that are difficult to discern by examining individual LGAs alone. For example, in the Sydney region there is a band of relatively low tree canopy stretching from the city's eastern suburbs to Parramatta in the west. Within this band lie older, established LGAs with relatively high population densities that developed along the Parramatta Road corridor with Sydney's expansion. Clearly, a strategic approach to managing urban heat in Sydney should focus on improving tree cover throughout this corridor.

At LGA scale, the league tables allow LGAs to benchmark their canopy cover with similar LGAs in Sydney and Australia-wide. In addition, the categorisation of land cover into tree canopy, low shrubs hard surface, grass-bare-ground can aid decision making on the best options for increasing tree cover within an LGA. For example, City of Sydney is pursuing a strategy to increase urban greening through the incorporation of vegetation into the existing built environment. Given the low level of grass-bare ground and the high proportion of the land covered by hard surface in Sydney, a strategy to promote green walls and rooves would appear to be a sound approach. In contrast, Camden, which lies on Sydney's south-western fringe, has almost 70% grass-bare ground cover and a relatively low cover of hard surface. This LGA has enormous potential to increase tree canopy through planting of open space.

Calculating the ratio of hard surface:tree and grass-bare ground:tree for LGAs with relatively low levels of tree cover provides a simple metric to aid strategic decision making. LGAs with high hard surface to tree cover ratios across Australia include Maribyrnong in Victoria, Fremantle in Western Australia, Holdfast Bay in South Australia and Rockdale in New South Wales (Tables 13). For these LGAs converting hard surface to tree planting would likely be the best approach to increase canopy cover. In contrast, Wyndham in Victoria, Wannaroo in Western Australia, Gawler in South Australia and Camden in New South Wales had high grass-bare ground to tree ratios which suggests the greatest potential to improve tree canopy cover in these areas would be to encourage new plantings on existing vacant land (Table 14). Some LGAs, such as Maribyrnong and

Brimbank appear in both tables indicating that there are multiple options for conversion of existing land cover to tree cover within these LGAs. We recognise that this metric does not attempt to account for variations in land tenure or use that would complicate the pursuit of a tree-planting program. The research outlined in Section 13 would assist to strengthen an understanding of the opportunities presented in Tables 12 and 13.

Table 12: Local Government Areas with the greatest potential to improve tree canopy through conversion of hard surface (highest HS:T ratio).

State	LGA	Tree canopy	Shrub	Hard surface	Grass-bare ground	LGA area	Ratio
		Percent Cover (%)				*km²*	*HS:T*
Vic	Maribyrnong, City of	7.4	3.6	58.2	30.8	31	7.88
Vic	Brimbank, City of	6.2	2.8	41.5	49.5	124	6.70
WA	Fremantle, City of	10.4	6.1	65.1	18.4	19	6.26
Vic	Hobsons Bay, City of	7.6	2.9	44	45.5	64	5.79
WA	Belmont, City of	9.1	9.5	50.6	30.8	40	5.55
WA	Vincent, City of	13.4	4.1	65.9	16.6	11	4.92
SA	Holdfast Bay, City of	13.4	3.5	65.8	17.3	14	4.90
Vic	Melbourne, City of	12.9	1.8	63	22.3	37	4.89
Vic	Greater Dandenong, City of	8.2	2.6	39.4	49.8	130	4.82
NSW	Rockdale, City of	12.4	4.5	58.1	25	28	4.67
SA	Port Adelaide Enfield, City of	11.9	2.6	55.1	30.4	92	4.65
NSW	Botany Bay, City of	12.1	2.8	55.4	29.7	22	4.56
NSW	Sydney, City of	15.2	2.5	69.1	13.2	27	4.55
Vic	Moonee Valley, City of	11.9	4.3	52.8	31	43	4.43
Vic	Wyndham, City of	3.1	2.7	12.9	81.3	543	4.17
SA	Charles Sturt, City of	13.2	4.5	54.8	27.5	55	4.15
WA	Canning, City of	13.1	7.2	53.1	26.6	65	4.06
WA	Bayswater, City of	13.2	8	53.5	25.3	33	4.06

* This table does not include SSDs of Brisbane or ACT

Table 13:Local Government Areas with the greatest potential to improve tree canopy through conversion of grass and bare ground (highest G-BG:T ratio)

State	LGA	Tree canopy	Shrub	Hard surface	Grass-bare ground	LGA area	Ratio
		Percent Cover (%)				*km²*	*G-BG:T*
Vic	Wyndham, City of	3.1	12.9	2.7	81.3	543	26.2
Vic	Melton, City of	6.3	6.0	2.7	85.0	529	13.4
Vic	Hume, City of	7.9	11.7	3.1	77.3	505	9.78
Vic	Brimbank, City of	6.2	41.5	2.8	49.5	124	7.99
Vic	Greater Geelong, City of	10.9	9.5	5.3	74.3	1,250	6.82
Vic	Greater Dandenong, City of	8.2	39.4	2.6	49.8	130	6.09
Vic	Hobsons Bay, City of	7.6	44.0	2.9	45.5	64	5.99
Vic	Casey, City of	12.6	19.9	7.2	60.3	410	4.78
WA	Wanneroo, City of	15	7.9	12.3	64.8	687	4.32
SA	Gawler, Town of	14.6	18.4	4.2	62.8	41	4.31
Vic	Ballarat, City of	17	10.0	1.5	71.5	740	4.20
Vic	Maribyrnong, City of	7.4	58.2	3.6	30.8	31	4.17
SA	Playford, City of	14.8	16.5	7.7	61.0	346	4.12
NSW	Camden Council	17	9.7	3.4	69.9	202	4.11
Vic	Whittlesea, City of	18.8	9.0	6.1	66.1	491	3.52
WA	Belmont, City of	9.1	50.6	9.5	30.8	40	3.40
Qld	Toowoomba Regional Council	23.8	1.0	4.2	71.0	13,008	2.98
SA	Onkaparinga, City of	18.9	11.2	15.2	54.7	519	2.90

* This table does not include SSDs of Brisbane or ACT

The presence of large public reserves in a LGA would likely skew tree canopy measurements over the whole land surface masking areas within the LGA where tree cover could usefully be increased. However, these LGAs have an advantage in that the presence of reserves would reduce the build-up of urban heat compared to LGAs without public reserves. Large public reserves in an LGA effectively reduce the pressure for additional large scale tree planting with implications for the return-on-investment to be gained from expanding the area of canopy.

Remote sensing of land cover and other landscape attributes using tools such as LiDAR is another option to analyse land cover. While LiDAR is doubtless invaluable as a research technique and provides information that cannot be revealed in other ways, our experience with i-Tree Canopy and Google Earth imagery suggest that simple, low cost, accessible tools can be equally effective to inform planning decisions, such as locating tree cover, at considerably reduced cost. It is likely that with the continued evolution of i-Tree it will be within the capabilities of local communities, environmental advocates and NGOs to employ it and similar open access software platforms to conduct their own mapping exercises in the near future.

We hope that the findings of this study can help to support local councils and communities in ongoing discussions about the importance of tree canopies, urban green space and urban heat. Inevitably, responsibility will fall upon local people to take ownership over the important land management decisions that affect their local landscapes.

13 MAXIMIZING RESEARCH OPPORTUNITIES

This study is the first step towards strengthening an understanding of land surface cover at a national, regional and local government scale. With the growing importance of tree cover in aiding human health and environmental issues, equipping LGAs with the necessary information to respond to urban vegetation problems is paramount. The analysis presented in this report is the first step in this research process by offering a high level overview of surface cover in Australia. However, to make this research useful and relevant for decision makers, further analysis is required to provide a more granular understanding of land use, land ownership along to better understand how, where and by whom urban greening strategies can be implemented.

For this research to be practical, relevant and usable for local councils, ISF recommend a three-stage research process:

Stage 1: Quantitative analysis: High-level land surface mapping

Stage 2: Quantitative analysis: Refinement of land surface mapping

Stage 3: Qualitative analysis: Understanding quality

Stage 1. Quantitative analysis: High-level land cover mapping (this report)

This outcome of this research has provided a quantitative analysis and mapping of land cover to identify broad patterns of tree cover, and land composition generally. High-level categorisation presents a broad overview of the trends within urban areas at three scales and identified broad opportunities at regional and LGA levels.

Stage 2. Quantitative analysis: Refinement of land cover mapping

Stage 1 analysis presents the proportions of land cover, including km^2 and percentage, for each of the 4 categories included in the analysis. While this is a useful starting point, the analysis has raised many questions that require answers for the information to be practically acted upon. These questions include:

Land ownership and opportunity for each LGA

- What proportion of the grass-bare ground is privately owned?
- What proportion of the grass-bare ground is publicly owned?
- How is grass-bare ground currently used (e.g. playing fields, parks, agriculture)?
- What is the km^2 and % of usable plant able areas that is publicly owned?
- Where are these publically owned areas of opportunity located?
- How much existing tree cover is within national parks, state forests or public reserves?
- How much of the hard surface proportions publicly owned, and where?
- Where are the opportunities for urban greening in areas of high hard surface proportions?

Outcome:

By providing answers to these questions, two primary outcomes would be achieved.

1. Land that is publicly owned, which can be utilised for tree cover and/or shrubs can be clearly identified and prioritised.
2. Proportions of private land can be identified, which can work to inform implementation strategies that encourage cooperation with private landowners.

Growth areas and planning

- Where are the designated growth areas within each of the areas of analysis?
- What proportions of currently categorised grass-bare land are earmarked for development?
- How will these developments affect density levels and proportions of green space?

Outcome:

By drawing upon existing planning and development maps, the maps and analysis from Stage 1 can be overlaid to isolate how and where planned developments will impact the opportunities for urban greening.

Socioeconomics

- How do the levels of tree cover identified in Stage 1 correspond with socioeconomic indexes?
- Is there a correlation between high levels of tree cover and affluence?

Outcome:

Due to the importance of human health in implementing to urban greening strategies, understanding the levels of social advantage and disadvantage is important at a regional and local government scale. Socio-Economic Indexes for Areas (SEIFA), provided by the Australian Bureau of Statistics, offers data at a LGA level indicating collective socioeconomic characteristics for people living in an area. Overlaying the data provided by SEIFA with the maps provided in Stage 1 can provide insights into the social correlations between land surface cover and socioeconomic status. As the impacts of the urban heat island effect continues to impact urban communities, particularly disadvantaged and marginalised groups, this type of analysis of is growing importance of decision makers and planners.

Stage 3. Qualitative analysis: Understanding quality

Once a thorough and more granular exploration of the opportunities, limitations and challenges facing urban greening has been conducted, understanding how notions of 'quality' can be measured, evaluated, and subsequently incorporated into planting strategies. To maximise the human and environmental benefits of urban greening strategies, an analysis of quality is recommended. This quality analysis would seek to answer questions such as;

- Which plant species would best suit the geography for human and environmental purposes?
- What are the human engagement patterns with new or existing vegetation?
- Where are the priority areas for planting native vegetation?
- What are the broader social impacts of urban greening?

This type of quality analysis will strengthen the likelihood to increasing canopy cover in areas that will have the maximum social and environmental benefits. To evaluate the less tangible social and human impacts, ISF recommend undertaking a Social Return on Investment (SROI) analysis. This in-depth social analysis will present a rigorous evidence base that captures the range of benefits that occur from urban greening in particular LGAs. This analysis can help to encourage and justify further urban greening initiatives by attributing a dollar value, along with the short term, and long-term outcomes of the initiative.

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