ArborCarbon *Creating Sustainable Ecosystems*

# Precision Airborne Measurement and Monitoring of Urban Forest Cover and Condition

## Western Suburbs Regional Organisation of Councils

*Report No. J20462*

*27th July 2020*

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# REVISION SCHEDULE

| Revision | Report Description | Submission Date | Author(s) |
|---|---|---|---|
| **A** | WESROC Urban Forest Canopy Cover Monitoring 2020 | 16/07/2020 | Briony Williams |
| **0** | WESROC Urban Forest Canopy Cover Monitoring 2020 | 27/07/2020 | Briony Williams |

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# Executive Summary

The Western Suburbs Regional Organisation of Councils (WESROC) is comprised of seven local governments (LGAs) who collaboratively work on projects across shared boundaries. WESROC is comprised of the Towns of Cambridge, Claremont, Cottesloe and Mosman Park, the Shire of Peppermint Grove, and the Cities of Nedlands and Subiaco. Many of these LGAs have urban forest strategies and policies in place, and it is necessary to measure and monitor canopy cover and condition over time, in order to evaluate the effectiveness of current policies.

The purpose of this project is to identify the extent of WESROC's existing tree canopy and vegetation cover as well as to provide associated data and heat island mapping. The information produced will:

- Benchmark tree canopy cover, and assist the development of vegetation KPIs to guide management policy
- Identify areas and streetscapes with below average levels of tree canopy for more targeted tree planting and replacement program
- Monitor the success of streetscape tree planting and revegetation efforts
- Use high resolution thermal imagery to identify 'Urban Heat Islands' which may be targeted for priority tree planting

High-resolution airborne multispectral imagery was acquired at 8,000 ft above ground level over the boundary with cloudless conditions between 10:30 and 15:45 on March 10th, 2020. Imagery was acquired for this project with the ArborCam system with a ground sample distance (GSD) ranging from 8 cm/pixel to 24 cm/pixel dependent on the spectral band. Imagery was comprised of three broad bands in the visible (VIS) region of the electromagnetic spectrum, and an additional seven narrow bands strategically positioned in the VIS and near infra-red (NIR) regions to detect subtle variations and changes in vegetation condition. The thermal imagery was acquired with a GSD of 100 cm/pixel.

The main findings of this report are:

- At the time of acquisition, on the 10th March 2020, WESROC had a total of 2371.4 ha of vegetation, covering 38.5% of the total area.
- Canopy (vegetation >3m in height) covered 18.3% of the total area, corresponding to 1128.7 ha.
- The majority of canopy fell into the 3-10m height stratum.
- Peppermint Grove had the greatest canopy cover as a proportion of total LGA area (22.4%), followed by Claremont (20.1%) and Subiaco (19.9%). Cottesloe had the lowest (14%) followed by Mosman Park (15.8%).
- The City of Nedlands had a total of 782.6 ha of vegetation across all strata, covering 39.9% of the City's total area. Canopy made up 18.5% of the City's total area.
- Of the City of Nedlands, Karrakatta had the highest canopy cover (26.1%) and Claremont and Swanbourne had the lowest (11.6 and 11.7% respectively).

- The City of Subiaco had a total of 190.3 ha of vegetation across all strata, covering 33.9% of the City's total area. Canopy made up 19.9% of the City's total area.
- Of the City of Subiaco, the South Ward had the highest canopy cover (24.7%) and the East Ward had the lowest (17.5%). Parks & Reserves had the highest canopy cover of all land use categories (34.7%), while Commercial & Municipal had the lowest (7.7%).
- The Town of Cambridge had a total of 857.5 ha of vegetation across all strata, covering 41.1% of the Towns total area. Canopy made up 19.4% of the Town's total area.
- Of the Town of Cambridge, Wembley Downs had the highest canopy cover (35.7%) followed by Floreat (22.7%). Jolimont had the lowest (13%) followed by Wembley (13.9%). Wembley Golf Course (36.8%) and Bold Park (26%) had the highest canopy cover of land use categories, while Mitchell Freeway (9.9%) and Water Corporation (13.4%) had the lowest. Town of Cambridge Managed Coastal Vegetation (0.7%) had the lowest canopy cover of all the natural areas in the Town of Cambridge.
- The Town of Cottesloe had a total of 127 ha of vegetation across all strata, covering 32.3% of the Towns total area. Canopy made up 14% of the Town's total area.
- Of the Town of Cottesloe, the East Ward had the highest canopy cover (18.2%) while the South Ward had the lowest (11.2%).

Based on the findings of this analysis, we recommend Airborne multispectral vegetation surveys over the WESROC group of Councils should be conducted on an annual or periodic basis to track changes in vegetation cover and condition over time and the data used to monitor and set achievable targets for future canopy cover and condition.

## Table of Contents

## List of Figures

# 1 Introduction

The Western Suburbs Regional Organisation of Councils (WESROC) is comprised of seven local governments (LGAs) who collaboratively work on projects across shared boundaries. WESROC is comprised of the Towns of Cambridge, Claremont, Cottesloe and Mosman Park, the Shire of Peppermint Grove, and the Cities of Nedlands and Subiaco. Many of these LGAs have urban forest strategies and policies in place, and it is necessary to measure and monitor canopy cover and condition over time, in order to evaluate the effectiveness of current policies.

ArborCarbon has recently developed a unique 11-band airborne multispectral and thermal camera system (ArborCam) optimized for the accurate detection of vegetation and subtle changes in vegetation condition. ArborCarbon was engaged by WESROC to acquire high resolution imagery for the measurement of vegetation cover and condition, and land surface temperatures, across the area using this camera system. The purpose of this project is to identify the extent of WESROC's existing tree canopy and vegetation cover as well as to provide associated data and heat island mapping. The information produced will:

- Benchmark tree canopy cover, and assist the development of vegetation KPIs to guide management policy
- Identify areas and streetscapes with below average levels of tree canopy for more targeted tree planting and replacement program
- Monitor the success of streetscape tree planting and revegetation efforts
- Use high resolution thermal imagery to identify 'Urban Heat Islands' which may be targeted for priority tree planting

# 2 Methods

## 2.1 Acquisition of high-resolution airborne imagery

High-resolution airborne multispectral imagery was acquired at 8,000 ft above ground level over the boundary with cloudless conditions between 10:30 and 15:45 on March 10th, 2020. Imagery was acquired for this project with the ArborCam system with a ground sample distance (GSD) ranging from 8 cm/pixel to 24 cm/pixel dependent on the spectral band. Imagery was comprised of three broad bands in the visible (VIS) region of the electromagnetic spectrum, and an additional seven narrow bands strategically positioned in the VIS and near infra-red (NIR) regions to detect subtle variations and changes in vegetation condition. The thermal imagery was acquired with a GSD of 100 cm/pixel. The maximum temperature recorded on the 10th March at Swanbourne (BoM reference: 009215) was 29.7°C (bom.gov.au).

## 2.2 Data processing and analysis

The high-resolution airborne imagery datasets were geometrically corrected and orthorectified using ArborCarbon's 2017 airborne datasets. A Digital Surface Model (DSM) was generated from the acquired imagery for the full extent of the Council and aligned to the publicly available Geoscience Australia LiDAR-derived 5m Digital Terrain Model (DTM) and ArborCarbon's own classified DTM. Vegetation was stratified into seven pre-determined height categories as follows: turf, 0-3m, 3-10m, 10-15m and >15m. Any vegetation greater than 3m in height classified as tree canopy.

The co-aligned thermal imagery was radiometrically corrected and converted to surface temperature in degrees Celsius by applying a standard emissivity correction of 0.95 across the scene.

Bands across the VIS-NIR were used to detect all living vegetation in sun and shadow. Vegetation that was not photosynthesizing at the time of acquisition, such as dead wood in tree crowns and dead grass, was not classified as vegetation. Condition statistics were calculated using the Vegetation Condition Index (VCI), which is defined as the ratio of NIR to red reflectance.

Height-stratified vegetation cover statistics were calculated for each LGA, and further categories based on suburb, land use or vegetation type, as determined by the LGA.

# 3 Results and Discussion

## 3.1 Datasets

The acquired data was processed to produce a high-resolution RGB imagery (Figure 1), False Colour Composite (FCC) imagery (Figure 2), a height-stratified vegetation cover dataset (Figure 3), land surface temperature (°C) (Figure 4) and Vegetation Condition Index (Figure 5) across WESROC.

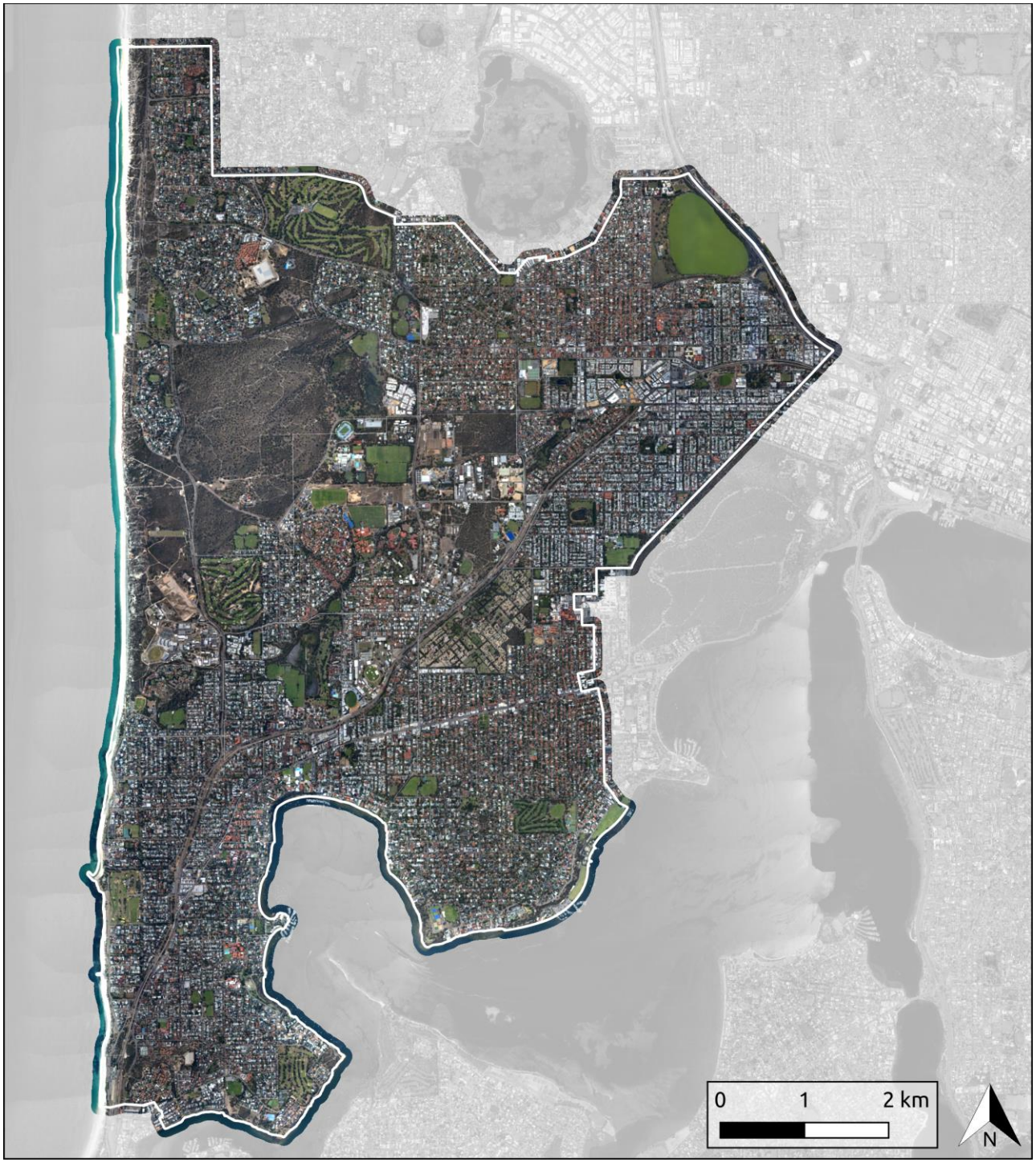



*Figure 1: High-resolution RGB imagery of WESROC.*

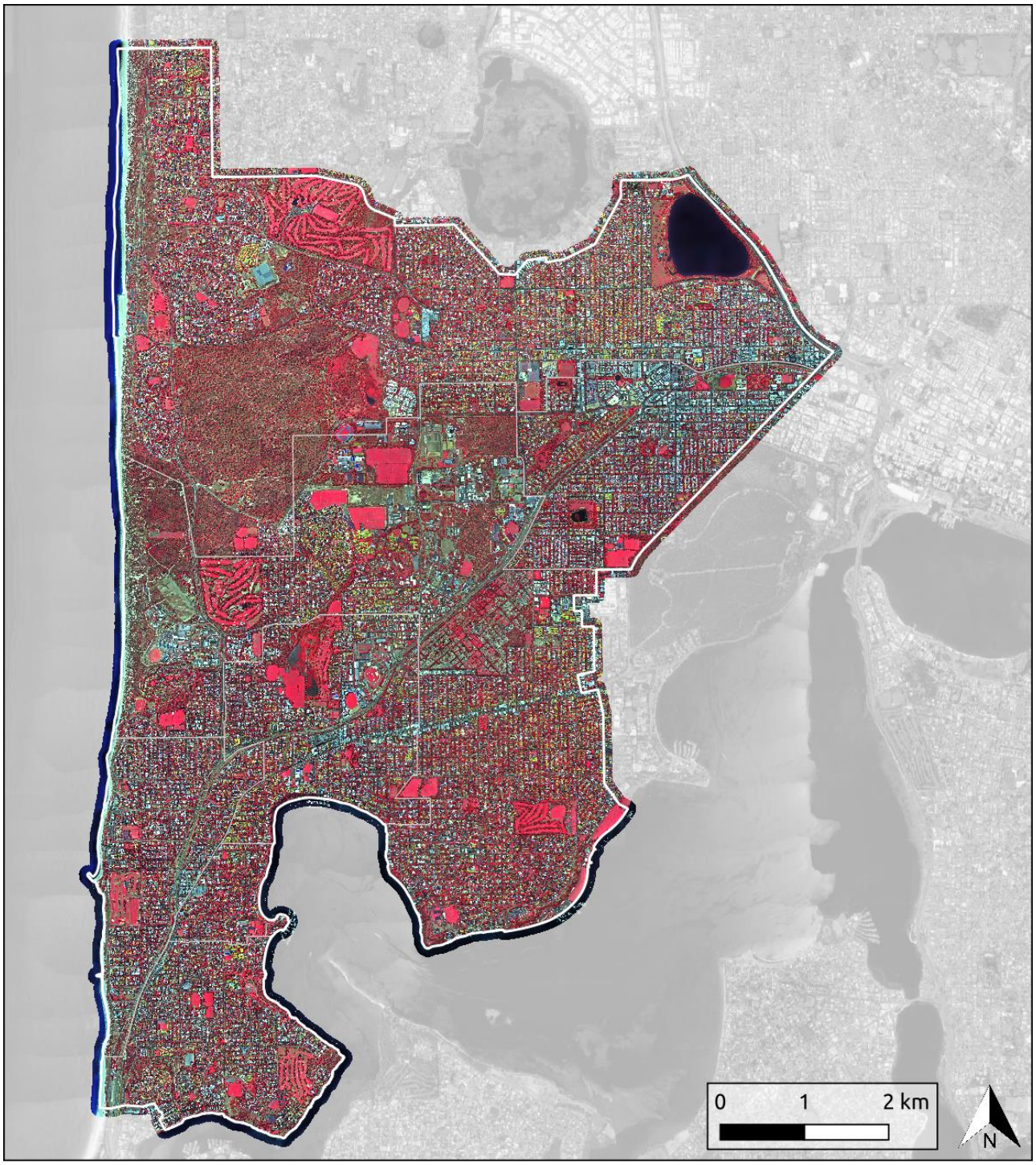



*Figure 2: False colour composite of WESROC showing vegetation (red pixels).*

The FCC dataset (Figure 2) was derived from a 3-band subset of the multispectral imagery (NIR, red and green). FCC imagery is commonly used in remote sensing to illustrate vegetation cover, which is displayed as red pixels.

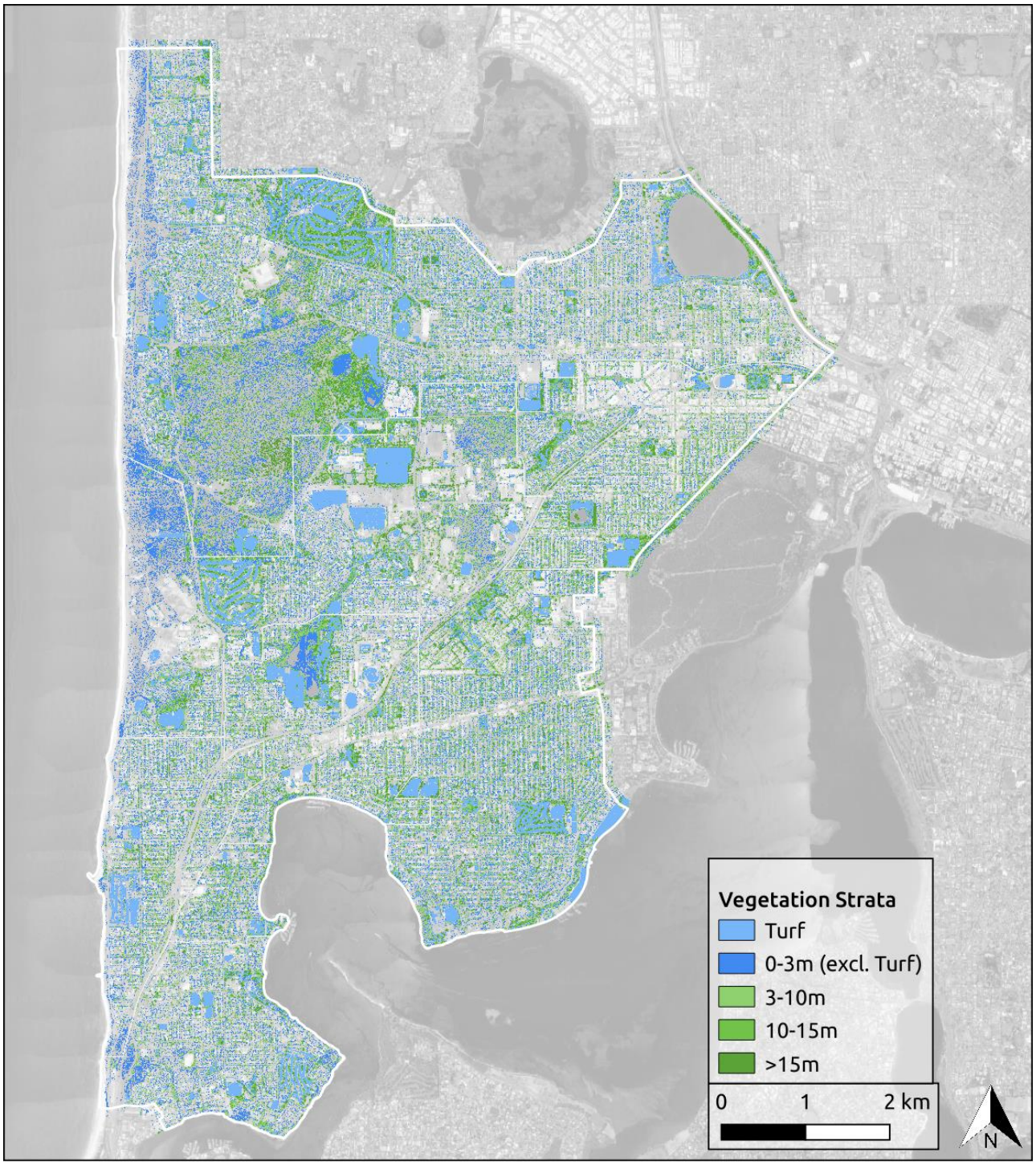



*Figure 3: Height-stratified vegetation dataset derived with each strata displayed in a different colour.*

The height-stratified vegetation cover dataset (Figure 3) consists of specific height strata as follows: light blue (turf), blue (0-3m), light green (3-10m), medium green (10-15m) and dark green (>15m). This colour scheme is used in all illustrations of the height-stratified dataset in this report.

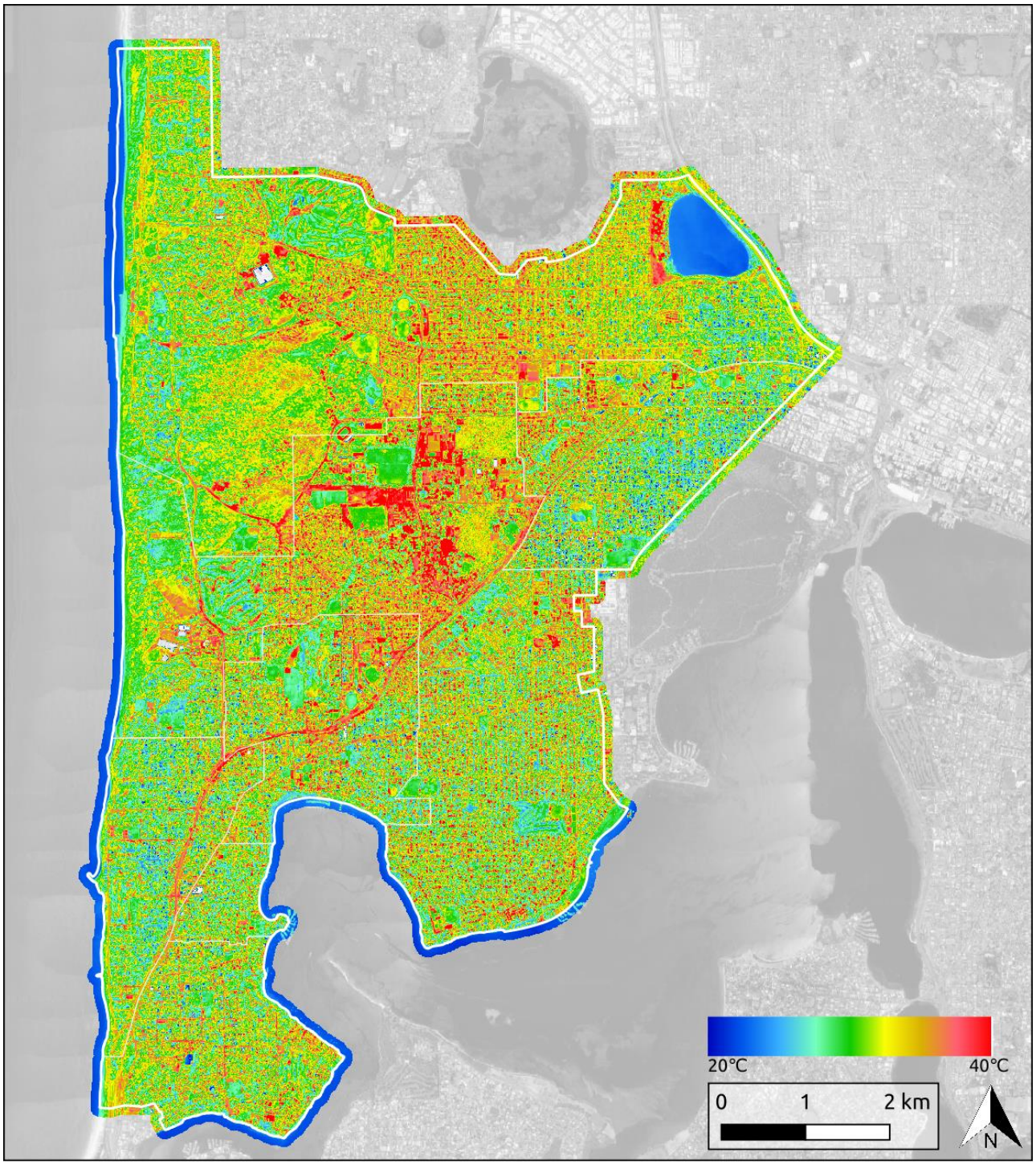



*Figure 4: Radiometrically corrected thermal orthomosaic land surface temperature of WESROC ranging from 20°C (blue) to 40°C (red).*

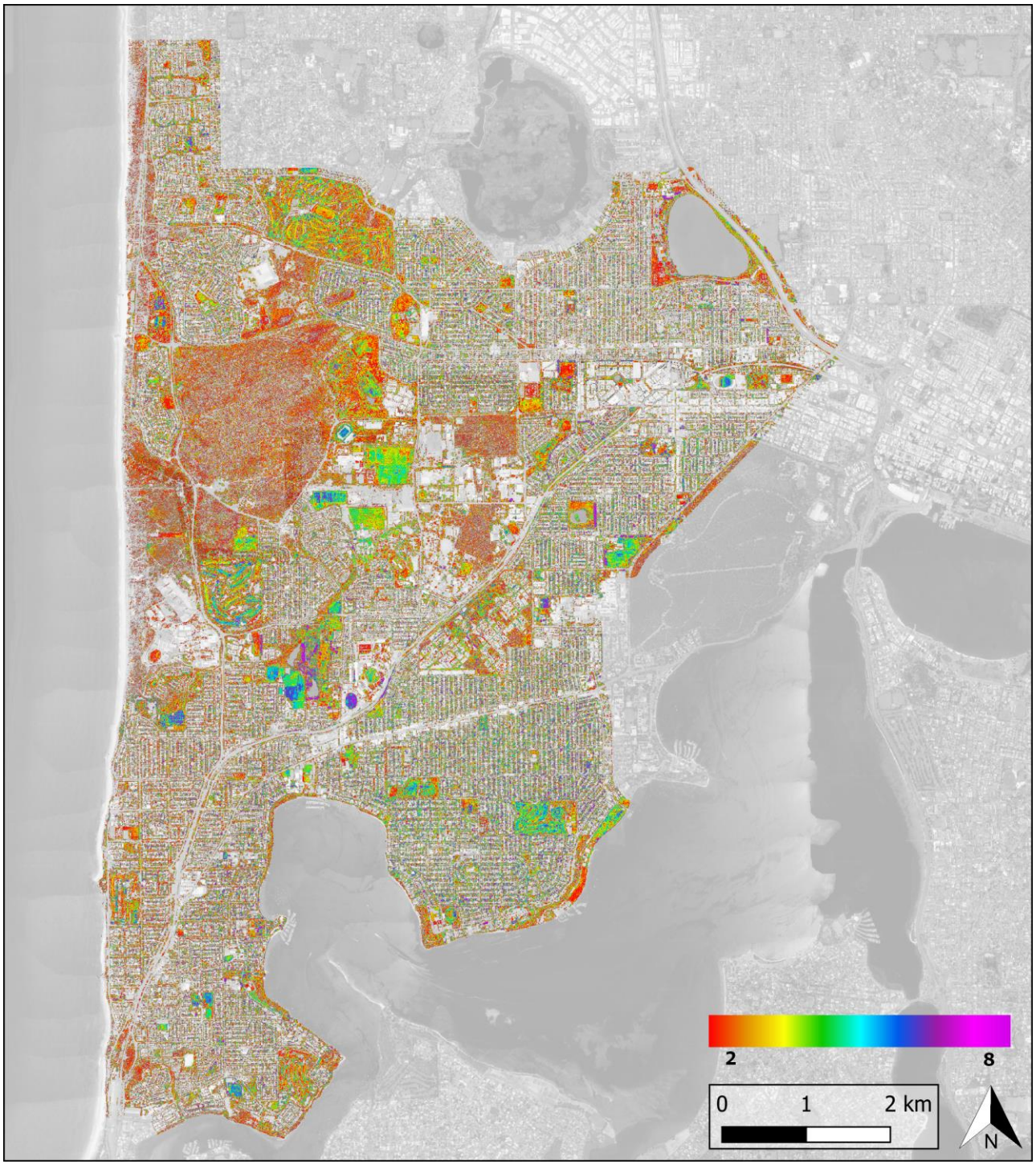



*Figure 5: Vegetation Condition Index (VCI) across WESROC, ranging from low (red) to high (purple).*

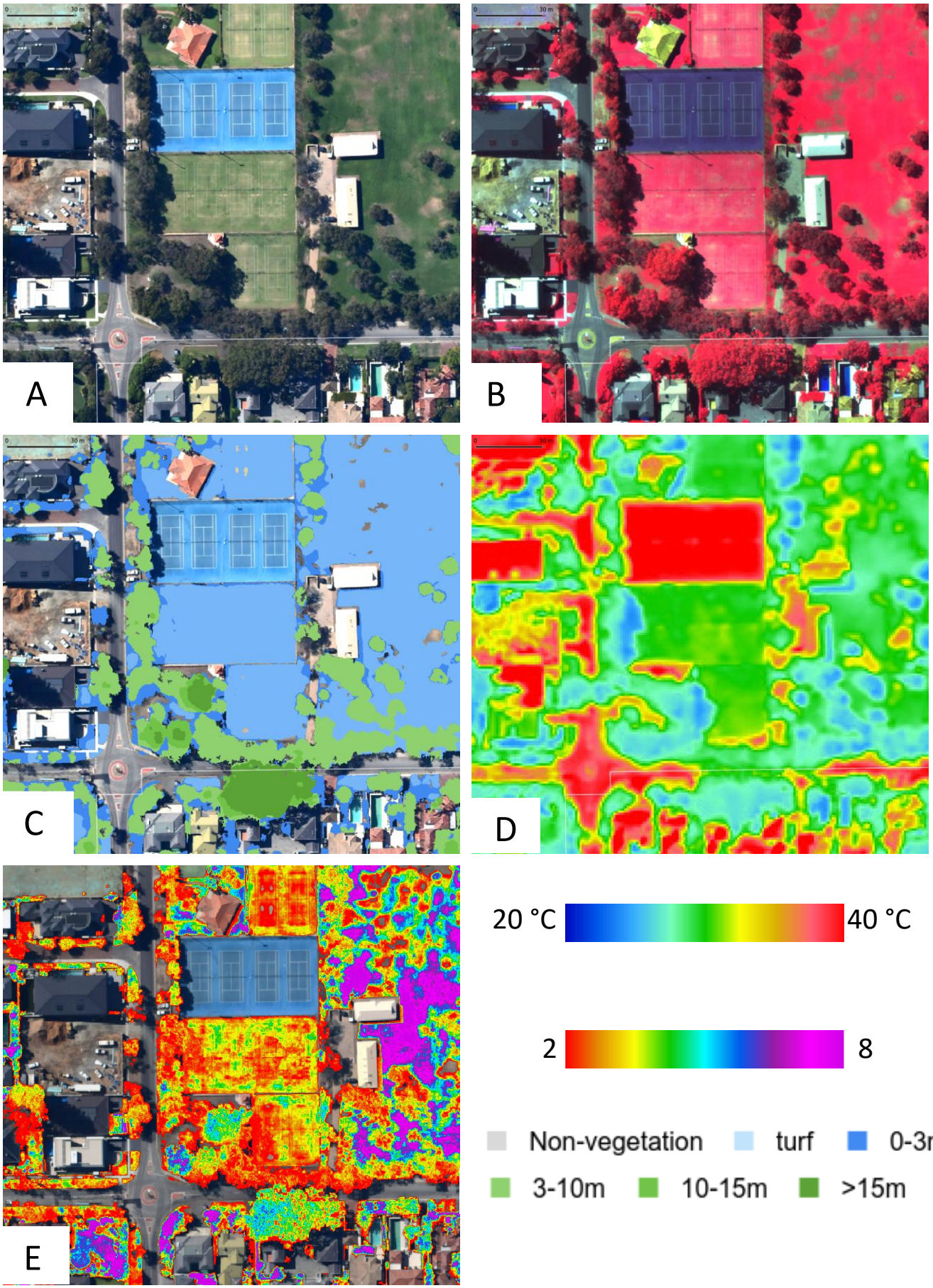

A
B
C
D
E
20 °C
40 °C
2
8
Non-vegetation
turf
0-3m
3-10m
10-15m
>15m

*Figure 6: Close-up image of each of the datasets generated for WESROC: A) High-resolution RGB imagery; B) FCC showing vegetation in red; C) Height-stratified vegetation cover, with each stratum displayed as a different colour; D) land surface temperature, ranging from low (20°C; blue) to high (40°C;red); and E) VCI showing vegetation condition, ranging from low (2; red) to high (8; purple).*

## 3.2 Analysis of vegetation cover

Height-stratified vegetation cover was calculated for all of WESROC, and for each of the LGAs that it comprises. Additional internal boundaries were provided for the Town of Cambridge, City of Subiaco, City of Nedlands, and the Town of Cottesloe. Vegetation cover and canopy statistics were calculated on these additional boundaries.

### 3.2.1 WESROC

WESROC is comprised of seven LGAs (Figure 7) covering an area of 6164.9 ha.

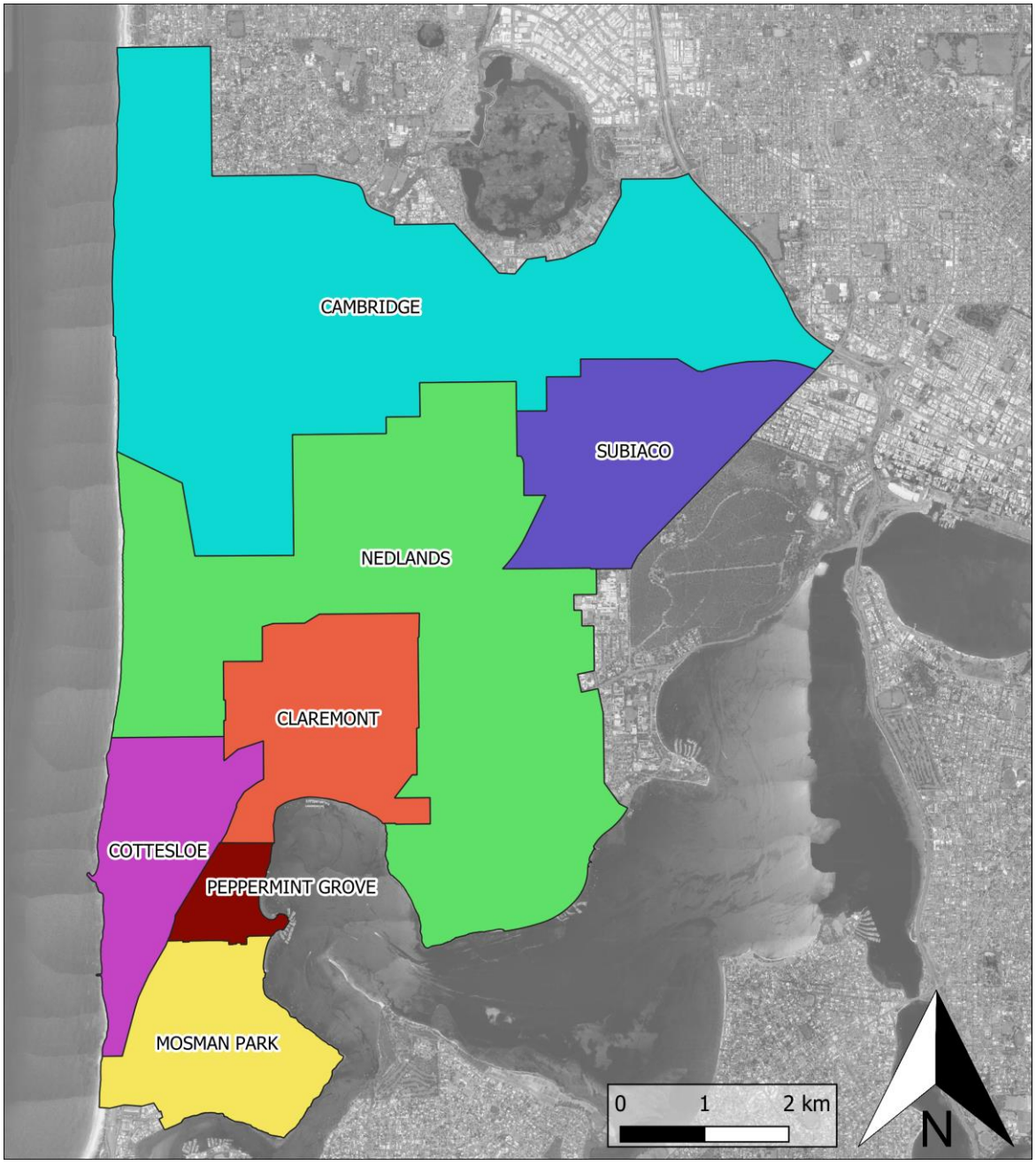



*Figure 7: WESROC and LGA boundaries.*

A total of 2371.4 ha of vegetation across all strata covered 38.5% of WESROCs total area, with the remaining 66.1% categorised as non-vegetation, such as buildings, roads, exposed soil and dead grass at the time of acquisition (Figure 8 A). Nearly two thirds of the vegetation were classified in the 0-3m (30.2%) or the 3-10m (29.4%) height strata (Figure 8 B). Turf made up 22.2% of WESROCs vegetation, while vegetation in the 10-15m height class contributed 9.8% and vegetation >15m in height contributed 8.4% to vegetation cover.

In total, canopy cover (vegetation >3m in height) comprised 47.6% of the vegetation in WESROC, or 1128.7 ha. This is 18.3% of the City's total area.

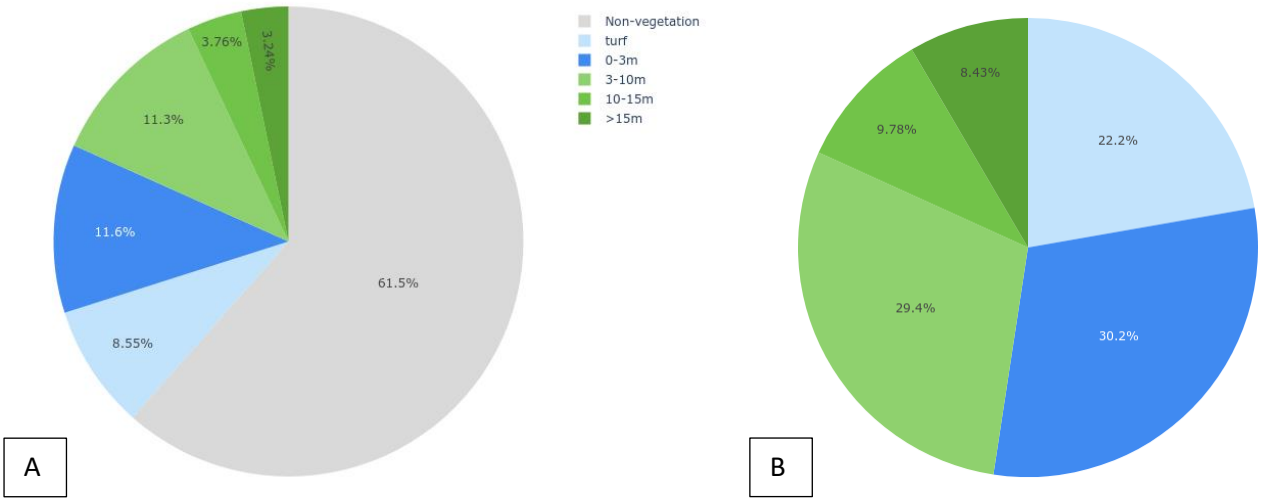



*Figure 8: Land cover by strata (%) (A) and vegetation cover by strata (%) (B) of WESROC.*

Canopy cover statistics were extracted for each LGA within WESROC (Figure 9). Peppermint Grove had the highest canopy cover as a proportion of the total area (22.4%), followed by Claremont (20.1%) and Subiaco (19.9%). Cottesloe had the lowest canopy cover (14%) followed by Mosman Park (15.8%).

Figure 9 represents canopy cover as a proportion of LGA area for each LGA in the WESROC area as a thematic map, with increasing green intensity corresponding to increasing proportional canopy cover. This information also appears in graphical form in Figure 10.

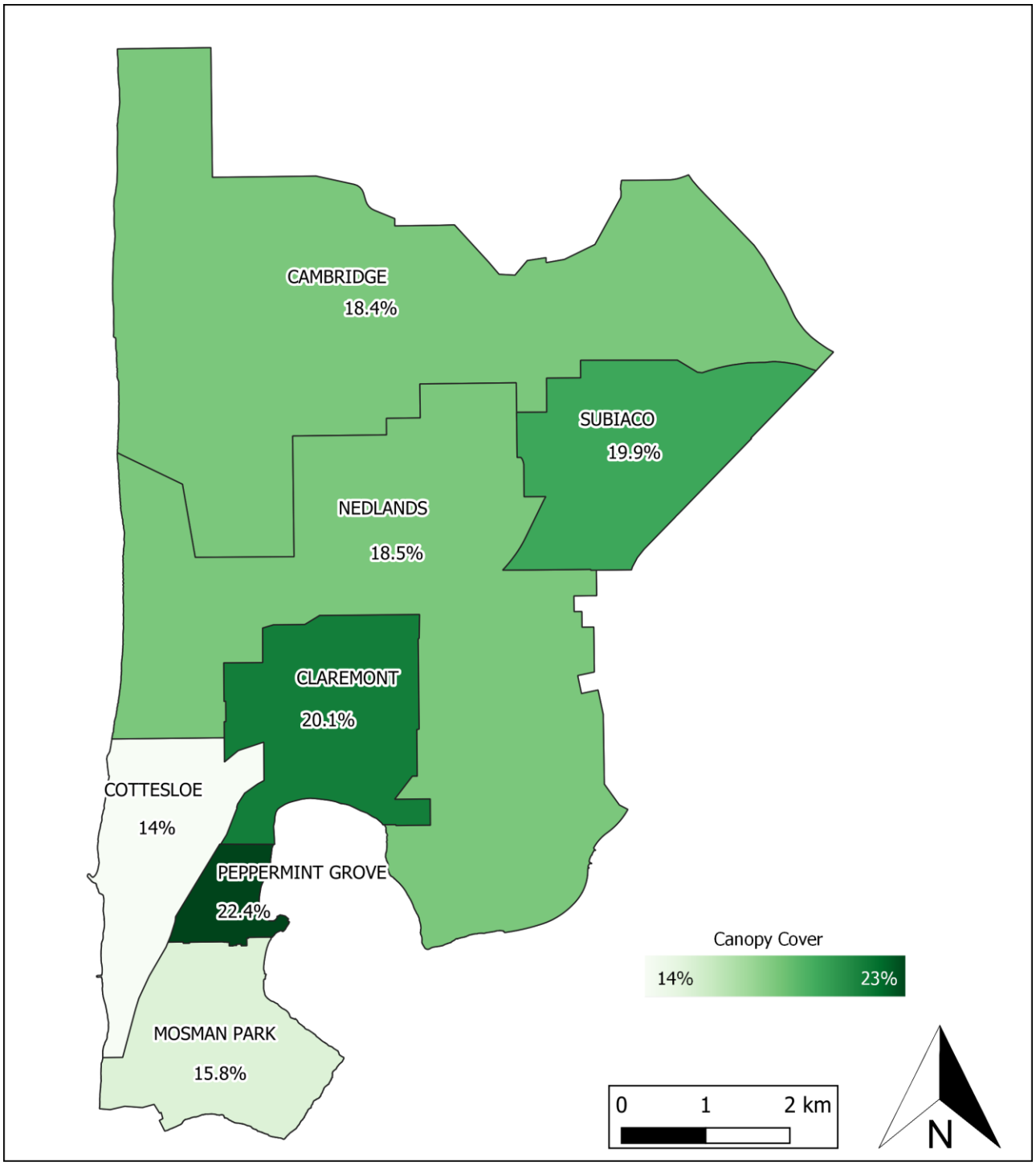



*Figure 9: Thematic map showing canopy cover as a percentage of total LGA area. The darker green indicates higher relative canopy cover percentage.*

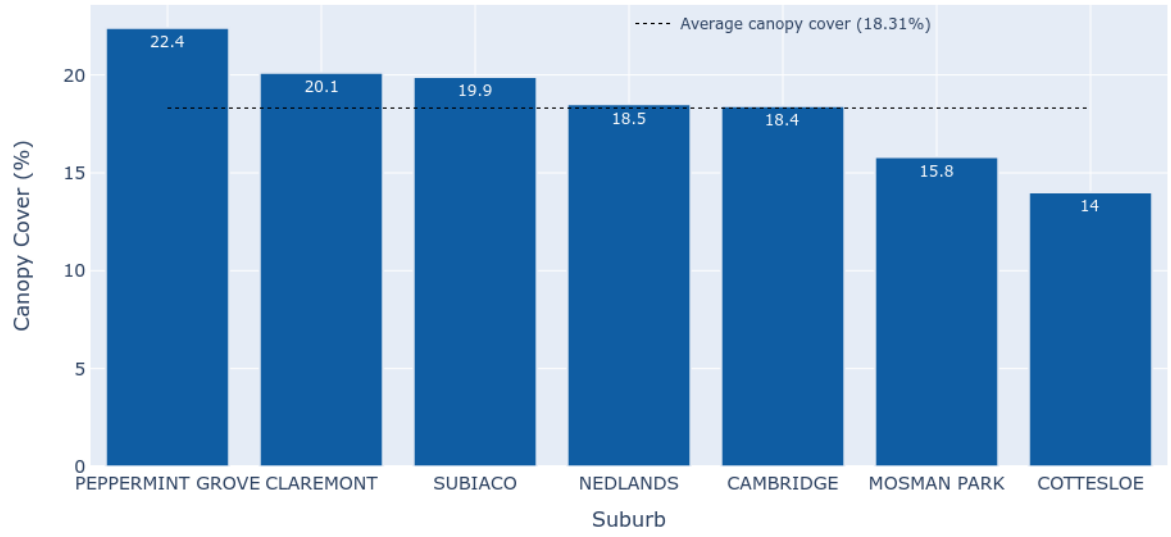



*Figure 10: Canopy cover of each LGA in WESROC by percentage of total suburb area.*

## 3.2.2 City of Nedlands

### *3.2.2.1 Council-wide*

Height-stratified vegetation cover was calculated across the entire City of Nedlands. The City is 1961.96 ha in size. A total of 782.6 ha of vegetation across all strata covered 39.9% of the City's total area (Figure 11 A), with the remaining 60.1% categorised as non-vegetation. Most vegetation was either classified as 3-10m in height (28.9%), 0-3m in height (28.2%) or turf (25.4%) (Figure 11 B). Vegetation in the 10-15m height strata contributed 9.5% to vegetation cover, and vegetation >15m in height comprised 7.9%. In total, canopy cover (vegetation >3m in height) comprised 46.3% of the vegetation in the City, or 362.6 ha. This is 18.5% of the City's total area.

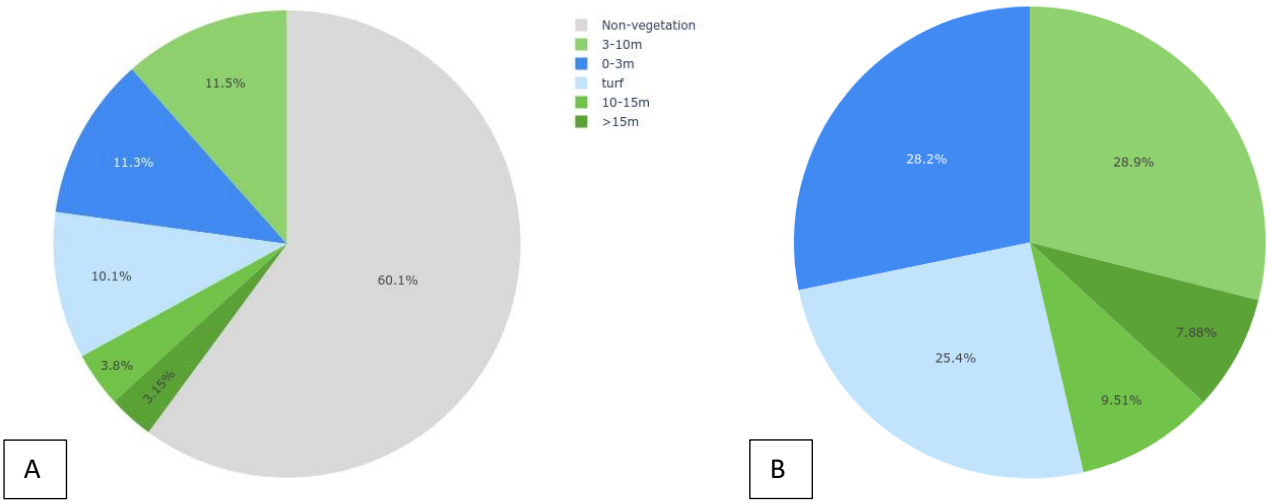



*Figure 11: Land cover by strata (%) (A) and vegetation cover by strata (%) (B) of The City of Nedlands.*

#### *3.2.2.2 Suburbs*

The City of Nedlands is comprised of eight suburbs (Figure 12).

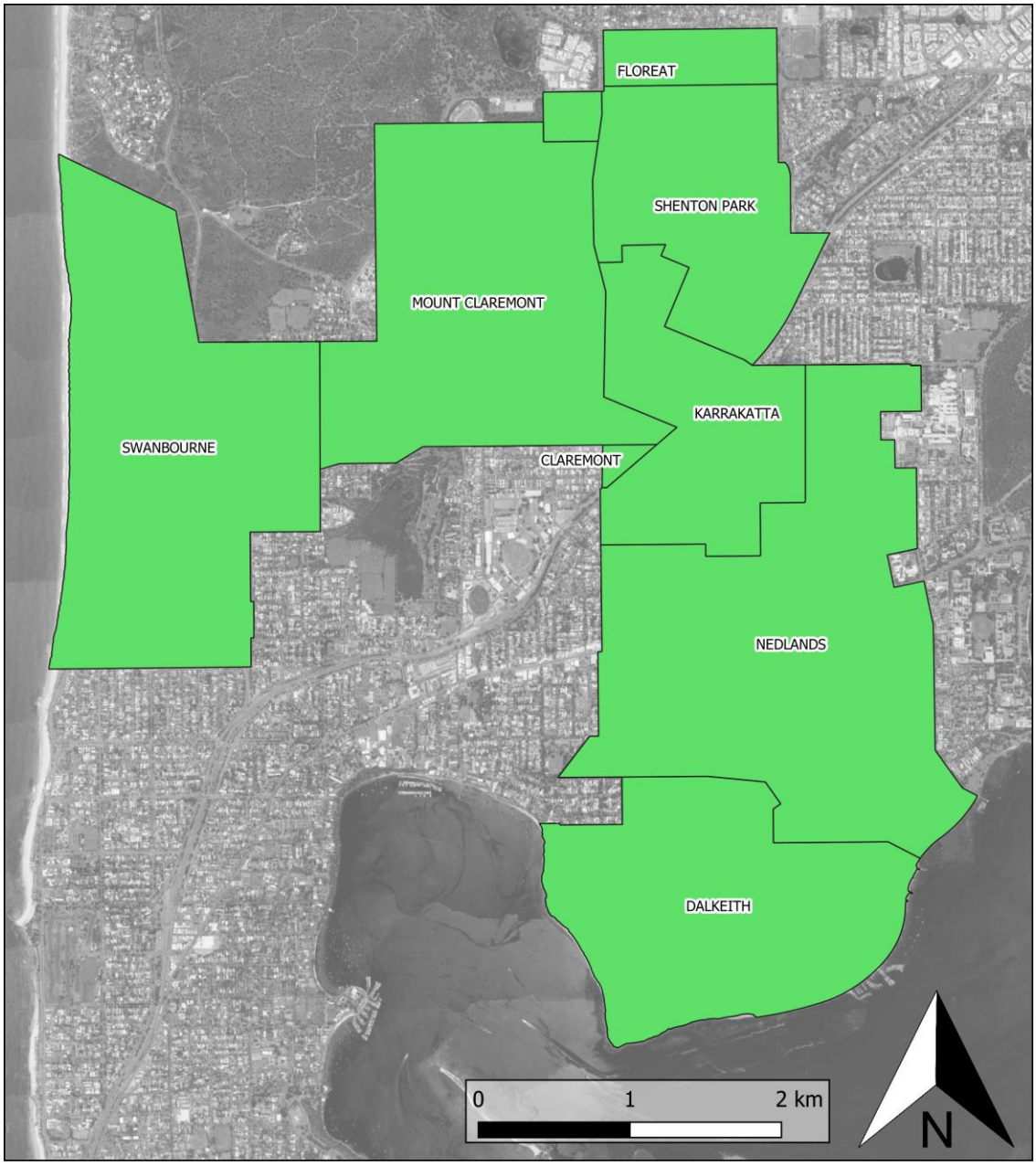



*Figure 12: City of Nedlands suburb boundaries.*

Canopy cover statistics were extracted for each suburb of the City of Nedlands (Figure 13). Karrakatta had the highest canopy cover as a proportion of total suburb area (26.1%), followed by Nedlands (21.4%) and Dalkeith (21.3%). Claremont had the lowest canopy cover (11.6%) followed by Swanbourne (11.7%).

Figure 13 represents canopy cover as a proportion of suburb area for each suburb in the City as a thematic map, with increasing green intensity corresponding to increasing proportional canopy cover. This information also appears in graphical form in Figure 14.

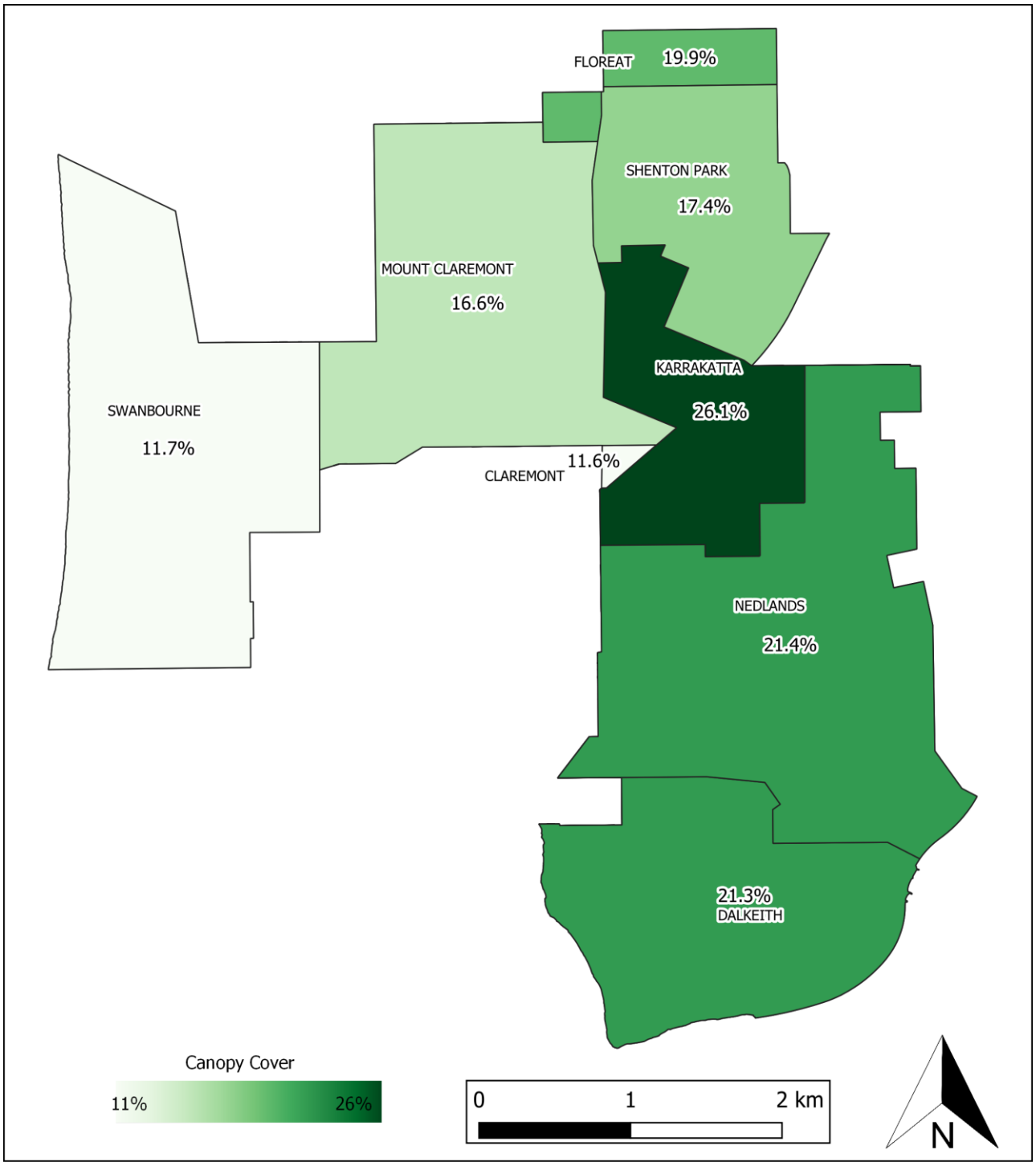



*Figure 13: Thematic map showing canopy cover as a percentage of total suburb area. The darker green indicates higher relative canopy cover percentage.*

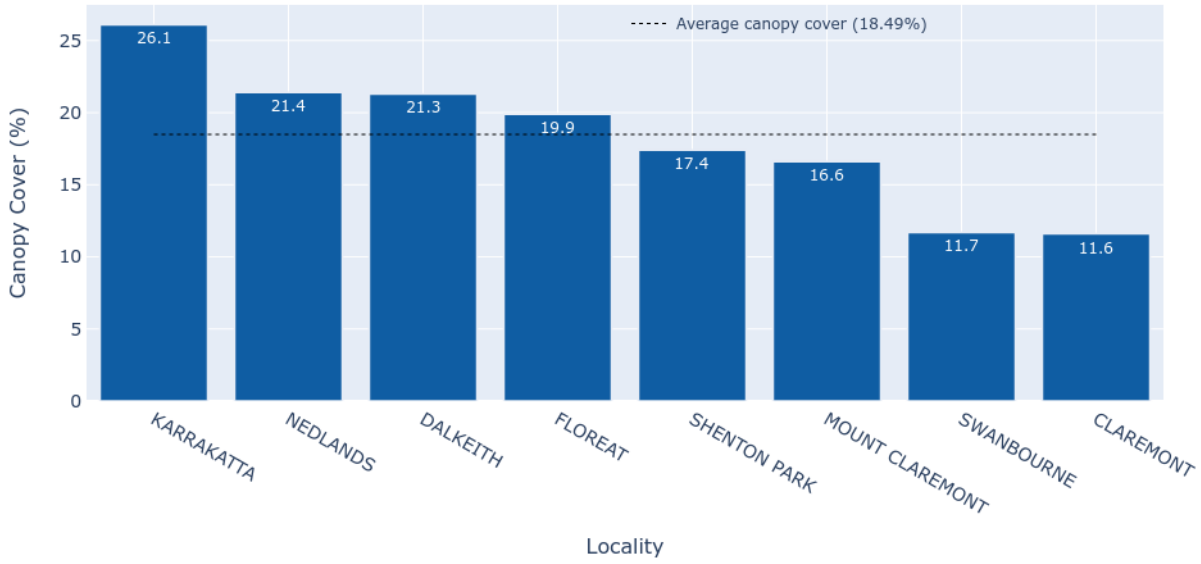



*Figure 14: Canopy cover of each suburb in the City of Nedlands by percentage of total suburb area.*

### 3.2.3 City of Subiaco

#### *3.2.3.1 Council-wide*

Height-stratified vegetation cover was calculated across the entire City of Subiaco. The City is 561.4 ha in size. A total of 190.3 ha of vegetation across all strata covered 33.9% of the City's total area, with the remaining 66.1% categorised as non-vegetation (Figure 15 A). Over a third (37.1%) of the vegetation was classified in the 3-10m height stratum (Figure 15 B). The next largest stratum was the 0-3m, which contained a quarter (24.9%) of the City's vegetation. Turf made up 16.4% of the City's vegetation, while vegetation in the 10-15m stratum made up 12.8% and vegetation >15m in height made up 8.9%. In total, canopy cover (vegetation >3m in height) comprised 58.8% of the vegetation in the City, or 111.8 ha. This is 19.9% of the City's total area.

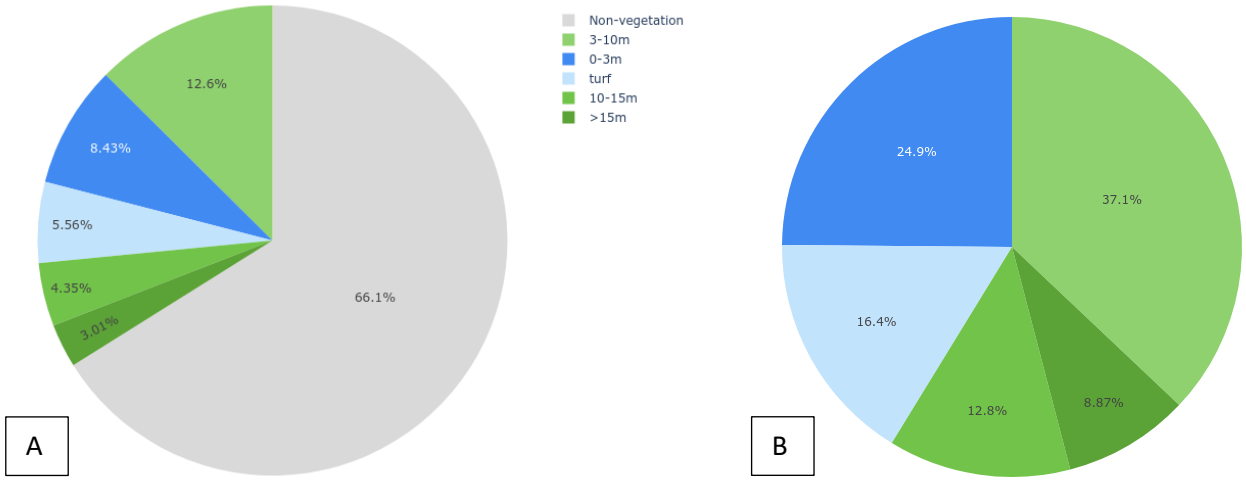



*Figure 15: Land cover by strata (%) (A) and vegetation cover by strata (%) (B) of the City of Subiaco.*

### *3.2.3.2 Wards*

The City of Subiaco is divided into four wards (Figure 16).

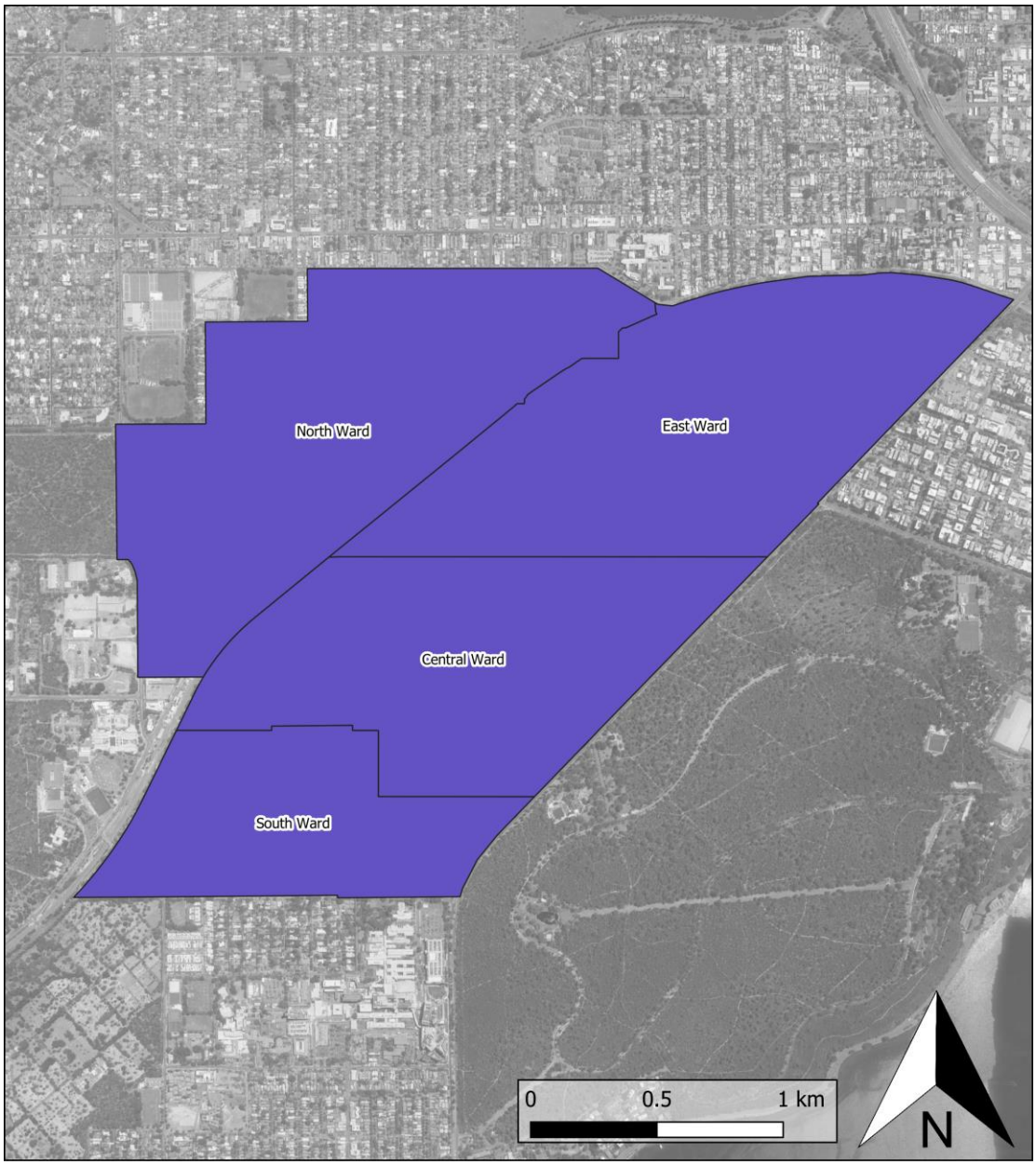



*Figure 16: City of Subiaco ward boundaries.*

Canopy cover statistics were extracted for each ward in the City of Subiaco (Figure 17). The south ward had the highest canopy cover as a proportion of total area (24.7%), followed by the central ward (21.7%), the north ward (18.5%), and finally the east ward (17.5%).

Figure 17 represents canopy cover as a proportion of ward area for each ward in the City as a thematic map, with increasing green intensity corresponding to increasing proportional canopy cover. This information also appears in graphical form in Figure 18.

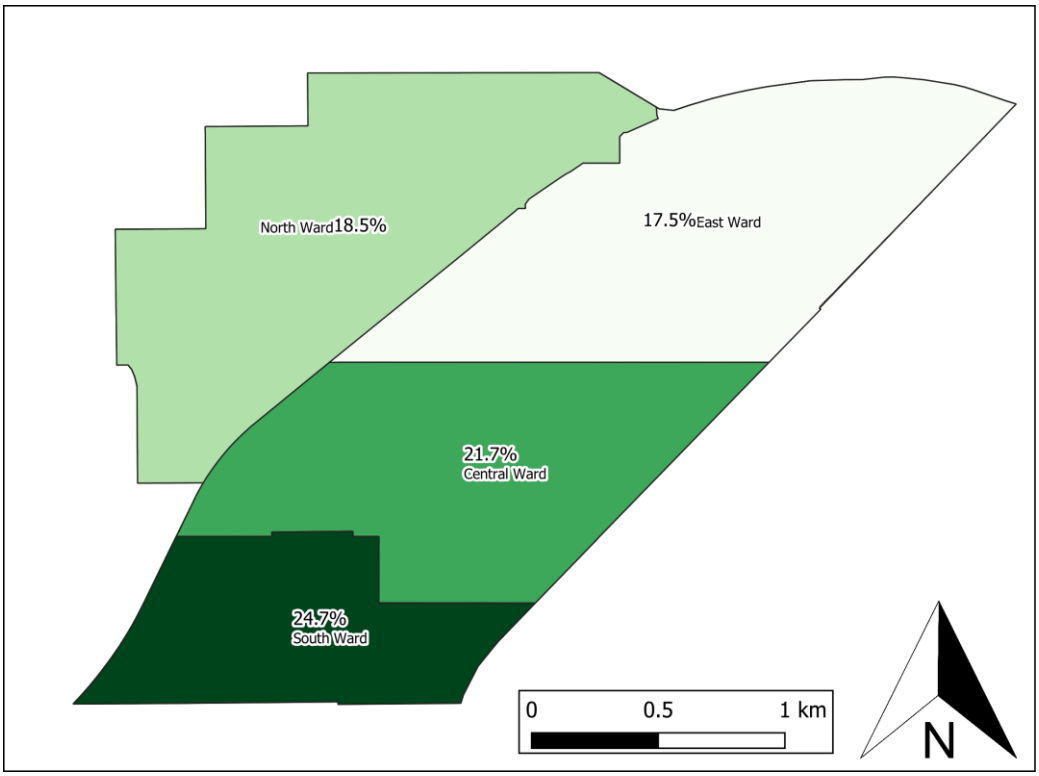



*Figure 17: Thematic map showing canopy cover as a percentage of total ward area. The darker green indicates higher relative canopy cover percentage.*

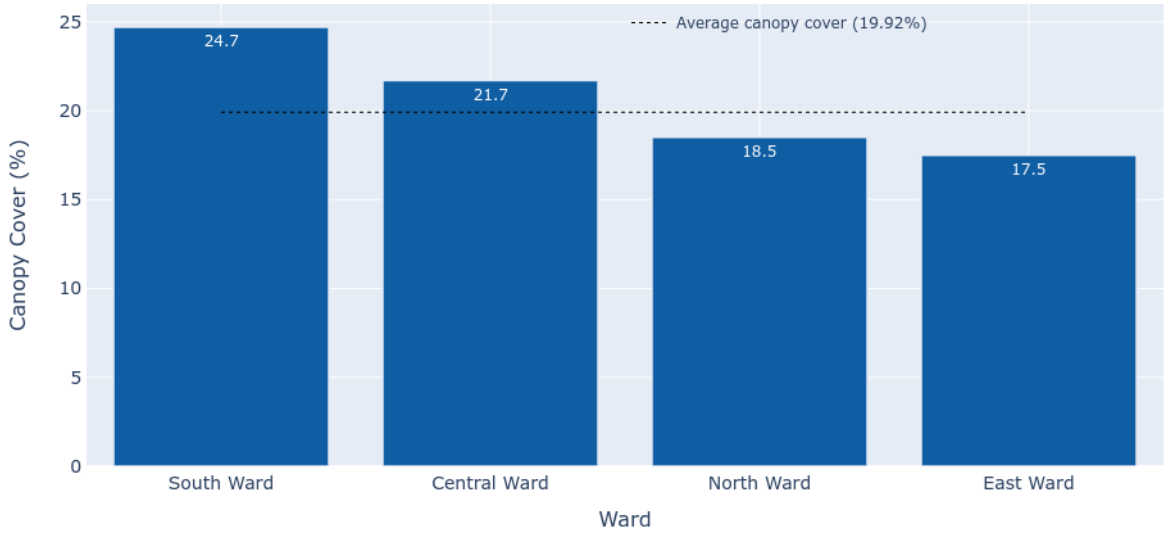



*Figure 18: Canopy cover of each ward in the City of Subiaco by percentage of total ward area.*

### *3.2.3.3 Land use type*

Canopy cover statistics were also calculated for each land use type within the City of Subiaco. The City has four different land use categories: Commercial & Municipal, Parks & Reserves, Residential, and Roads & Road Reserves (Figure 19).

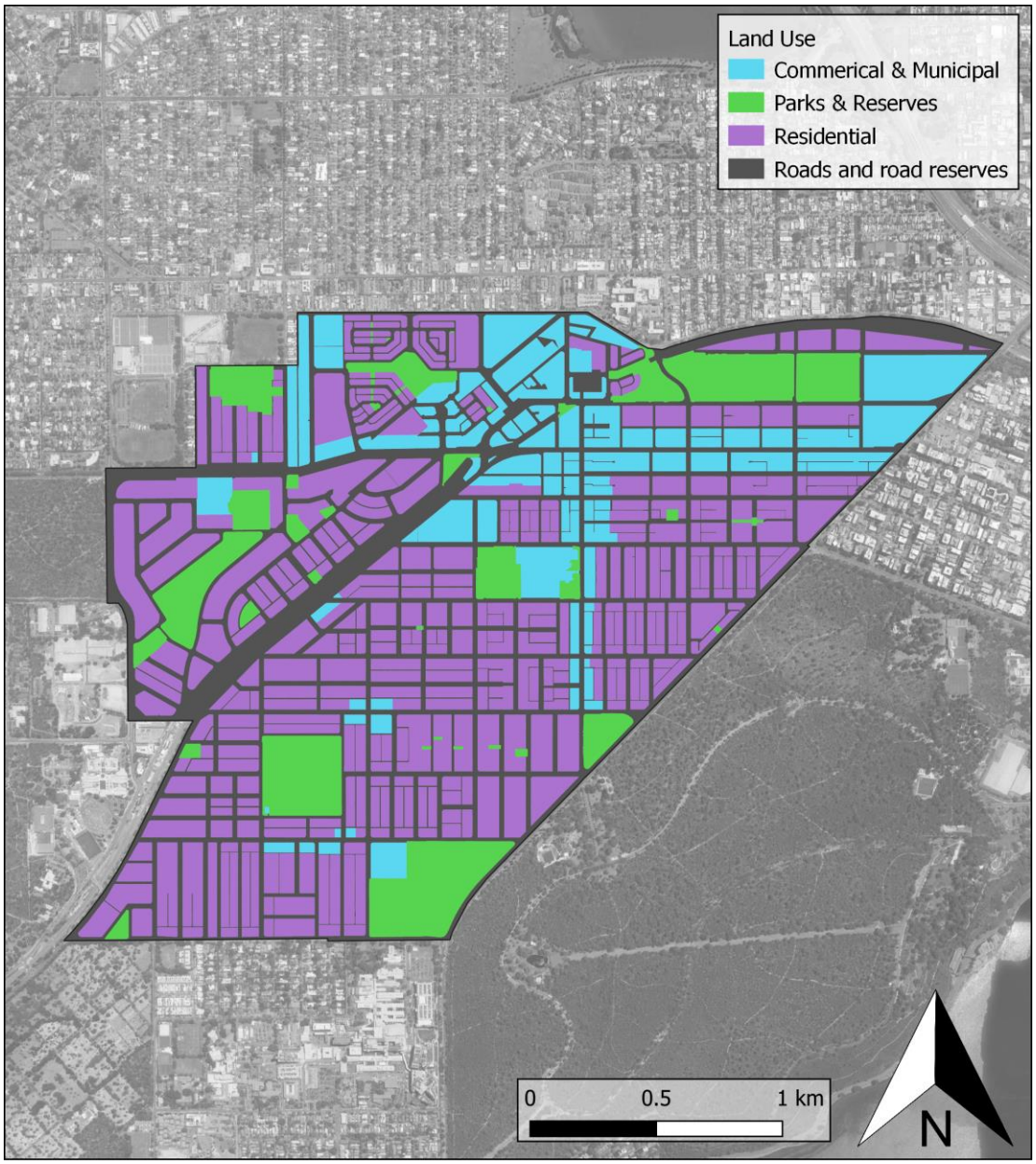



*Figure 19: Land use type boundaries within the City of Subiaco.*

The land use category with the greatest proportional canopy cover was Parks & Reserves (34.7%, Figure 20). Roads & Road Reserves had the second most proportional canopy cover (28%), followed by Residential (14.3%). Commercial & Municipal had the least (7.7%).

Figure 20 represents canopy cover as a proportion of land use area for each land use category in the City as a thematic map, with increasing green intensity corresponding to increasing proportional canopy cover. This information also appears in graphical form in Figure 21.


*Figure 20: Thematic map showing canopy cover as a percentage of land use area. The darker green indicates higher relative canopy cover percentage.*

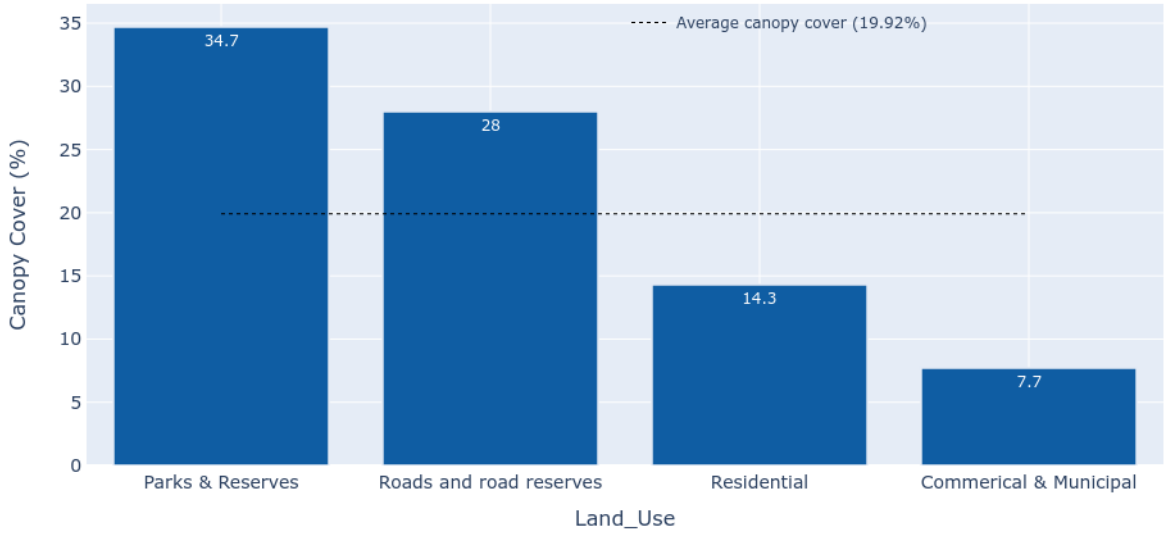



*Figure 21: Canopy cover of each land use type in the City of Subiaco by percentage of total land use type area.*

### 3.2.4 Town of Cambridge

#### *3.2.4.1 Council-wide*

Height-stratified vegetation cover was calculated across the entire Town of Cambridge. The Town of Cambridge is 2086.7 ha in size. A total of 857.5 ha of vegetation across all strata covered 41.1% of the Towns total area, with the remaining 58.9% categorised as non-vegetation (Figure 22 A). Nearly one third of the vegetation was classified in the 0-3m height stratum (Figure 22 B). The next largest stratum was the 3-10m, which contained 26.3% of the Town's vegetation. Turf made up 21.1% of the Town's vegetation, while vegetation in the 10-15m and >15m strata made up approximately 10% each. In total, canopy cover (vegetation >3m in height) comprised 47.3% of the vegetation in the Town, or 405.6 ha. This is 19.4% of the Town's total area.

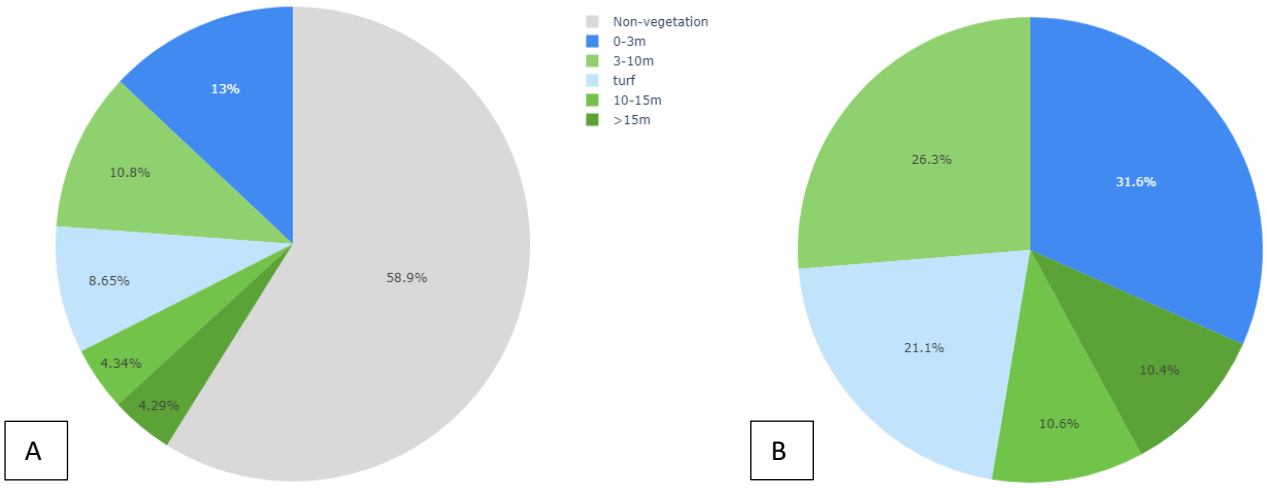



*Figure 22: Land cover by strata (%) (A) and vegetation cover by strata (%) (B) of the Town of Cambridge.*

#### *3.2.4.2 Suburbs*

The Town of Cambridge is comprised of seven suburbs (Figure 23).

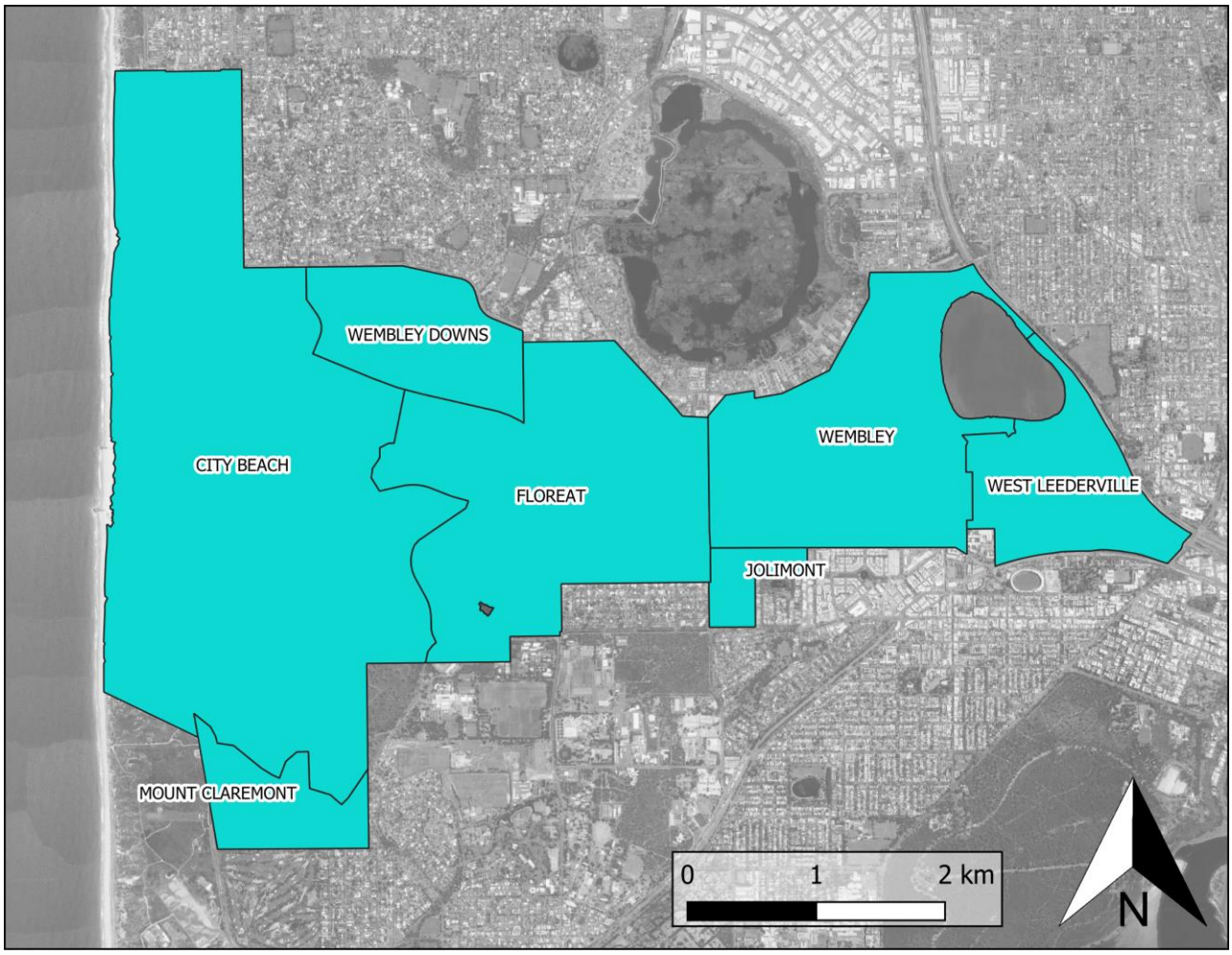



*Figure 23: Town of Cambridge suburb boundaries.*

Canopy cover statistics were extracted for each suburb (Figure 24). Wembley Downs had the highest canopy cover as a proportion of total suburb area (35.7%), followed by Floreat (22.7%) and City Beach (18.3%). Jolimont had the lowest canopy cover (13%) followed by Wembley (13.9%).

Figure 24 represents canopy cover as a proportion of suburb area for each suburb in the City as a thematic map, with increasing green intensity corresponding to increasing proportional canopy cover. This information also appears in graphical form in Figure 25.

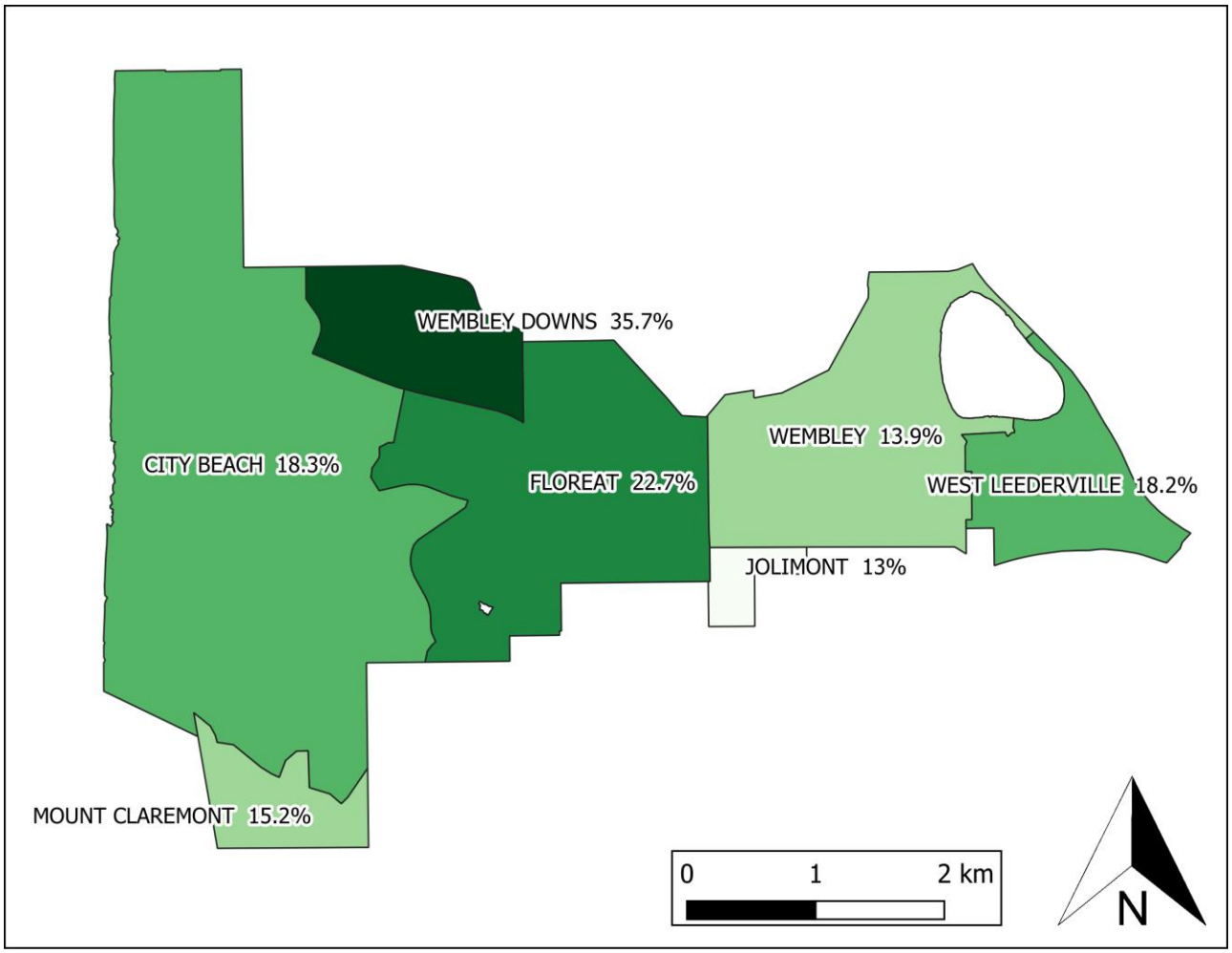



*Figure 24: Thematic map showing canopy cover as a percentage of suburb area. The darker green indicates higher relative canopy cover percentage.*

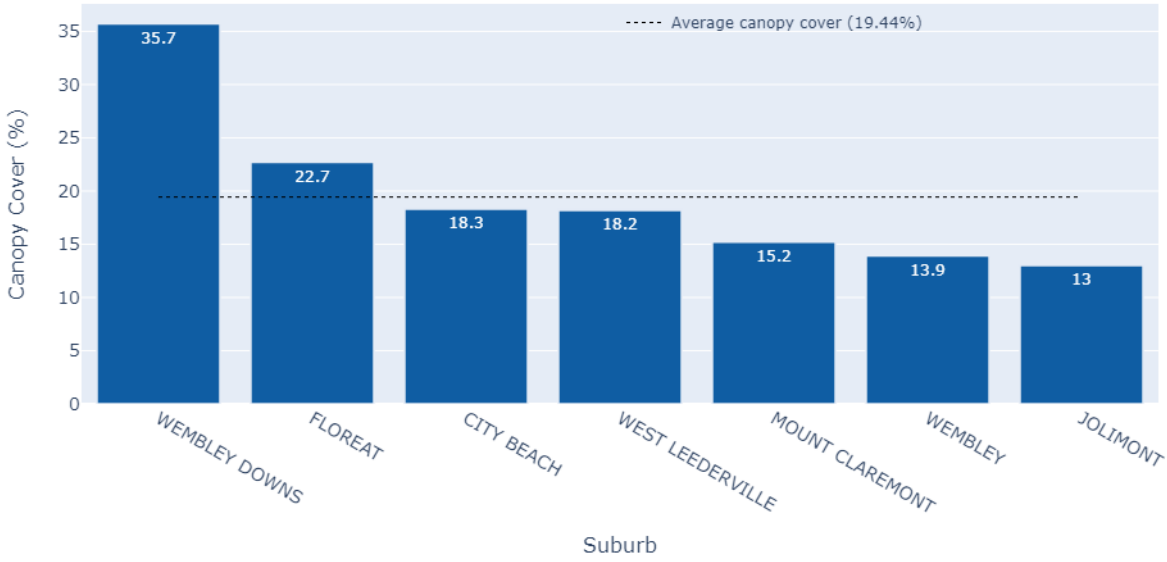



*Figure 25: Canopy cover of each suburb in the City of Subiaco by percentage of total suburb area.*

#### 3.2.4.3 Land use type

Canopy cover statistics were also calculated for each land use type within the Town of Cambridge. The different land use categories are illustrated in Figure 26.

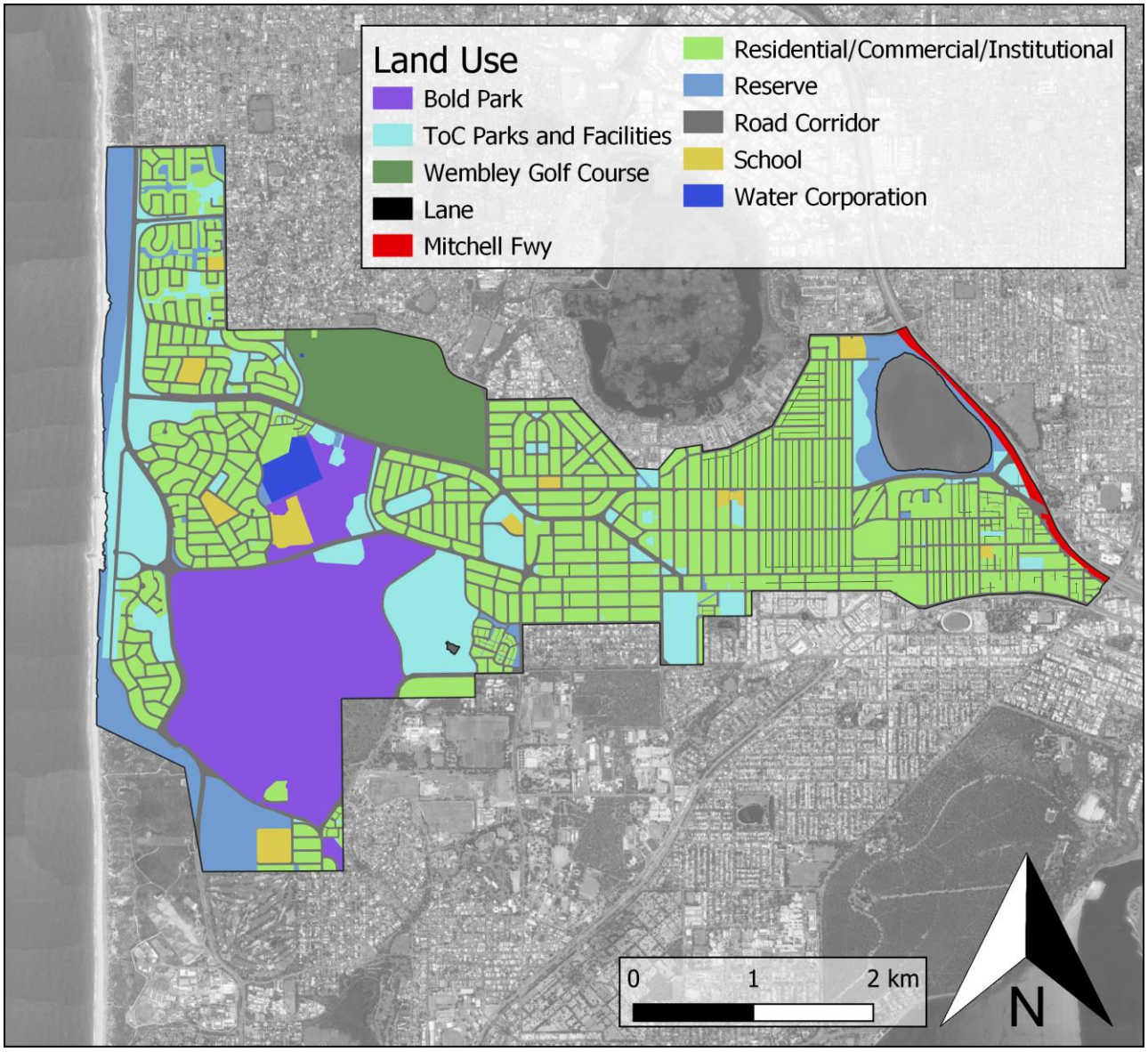



*Figure 26: Land use type boundaries within the Town of Cambridge.*

The land use category with the greatest proportional canopy cover was Wembley Golf Course (34.7%, Figure 27), followed by Bold Park (26%), ToC Parks & Facilities (24.9%) and Schools (19.8%). The Mitchell Fwy had the lowest canopy cover of 9.9%.

Figure 27 represents canopy cover as a proportion of land use area for each land use category in the Town as a thematic map, with increasing green intensity corresponding to increasing proportional canopy cover. This information also appears in graphical form in Figure 28.

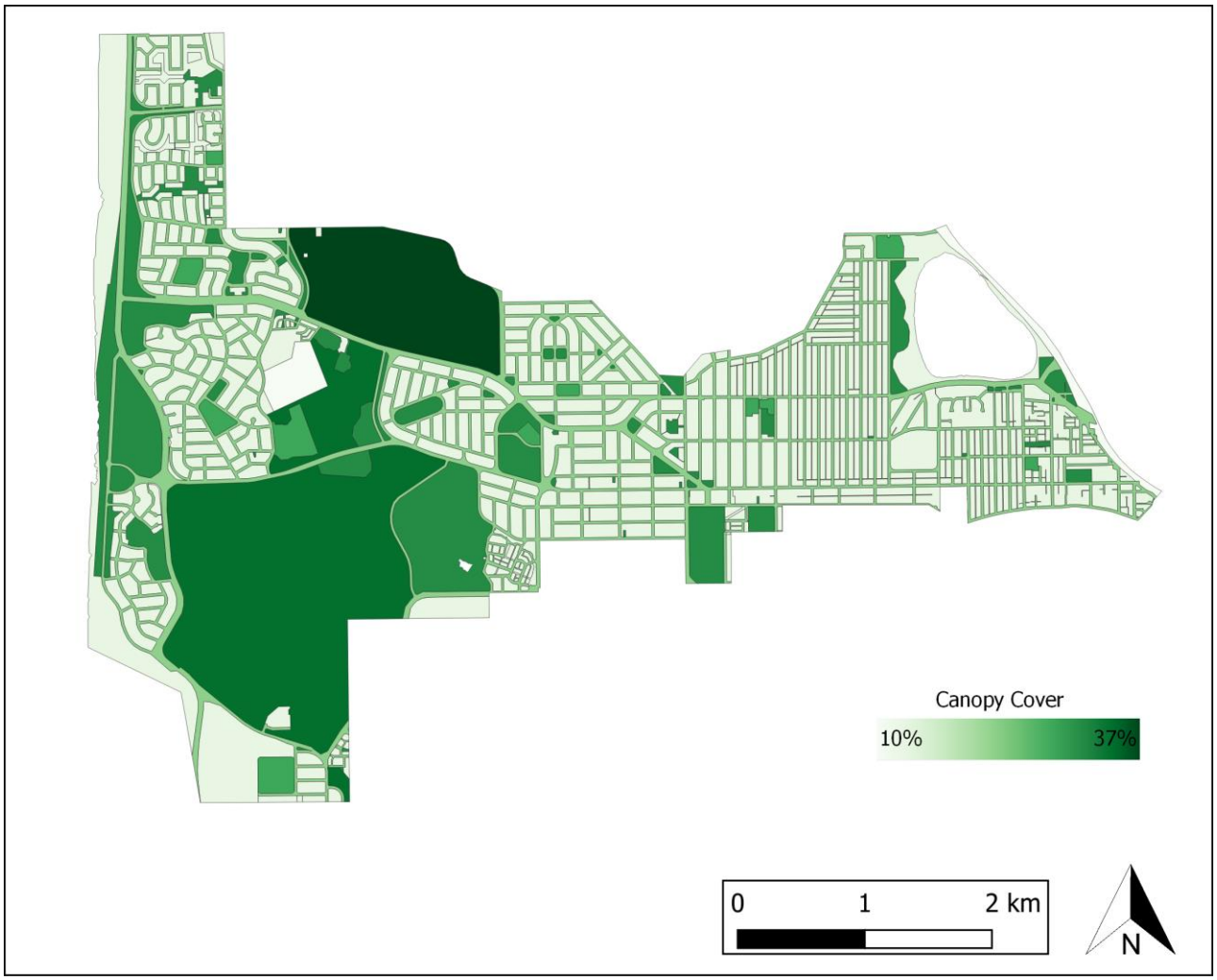



*Figure 27: Thematic map showing canopy cover as a percentage of land use area. The darker green indicates higher relative canopy cover percentage.*

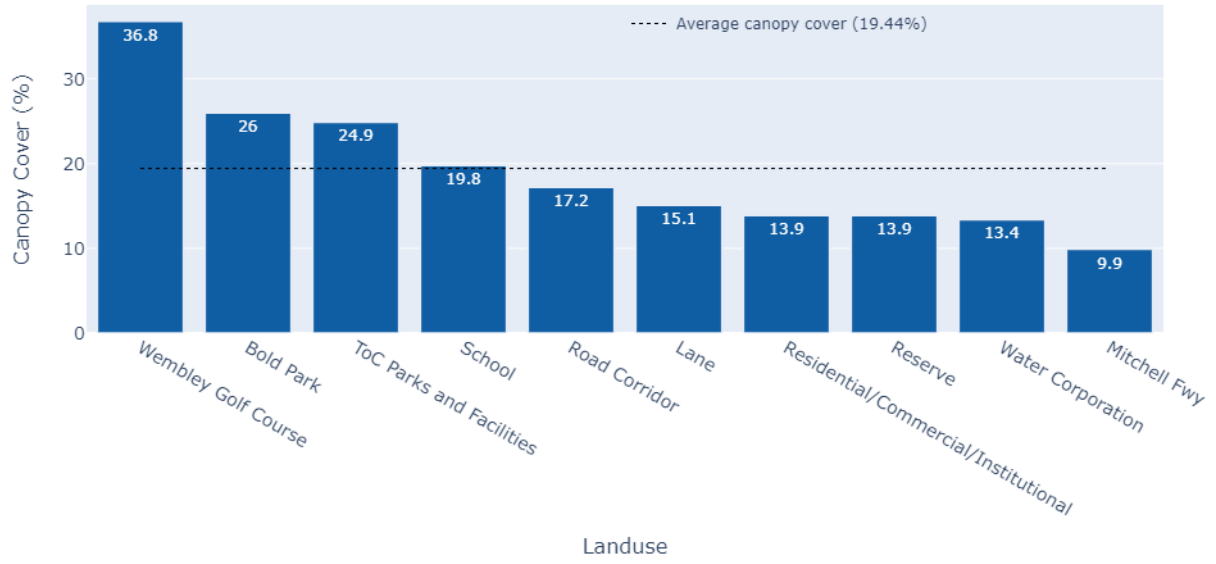



*Figure 28: Canopy cover of each land use type in the Town of Cambridge by percentage of total land use type area.*

#### *3.2.4.4 Vegetation type*

Canopy cover statistics were calculated for vegetation types throughout the Town of Cambridge. There are six different categories of vegetation in the Town, as illustrated in Figure 29.

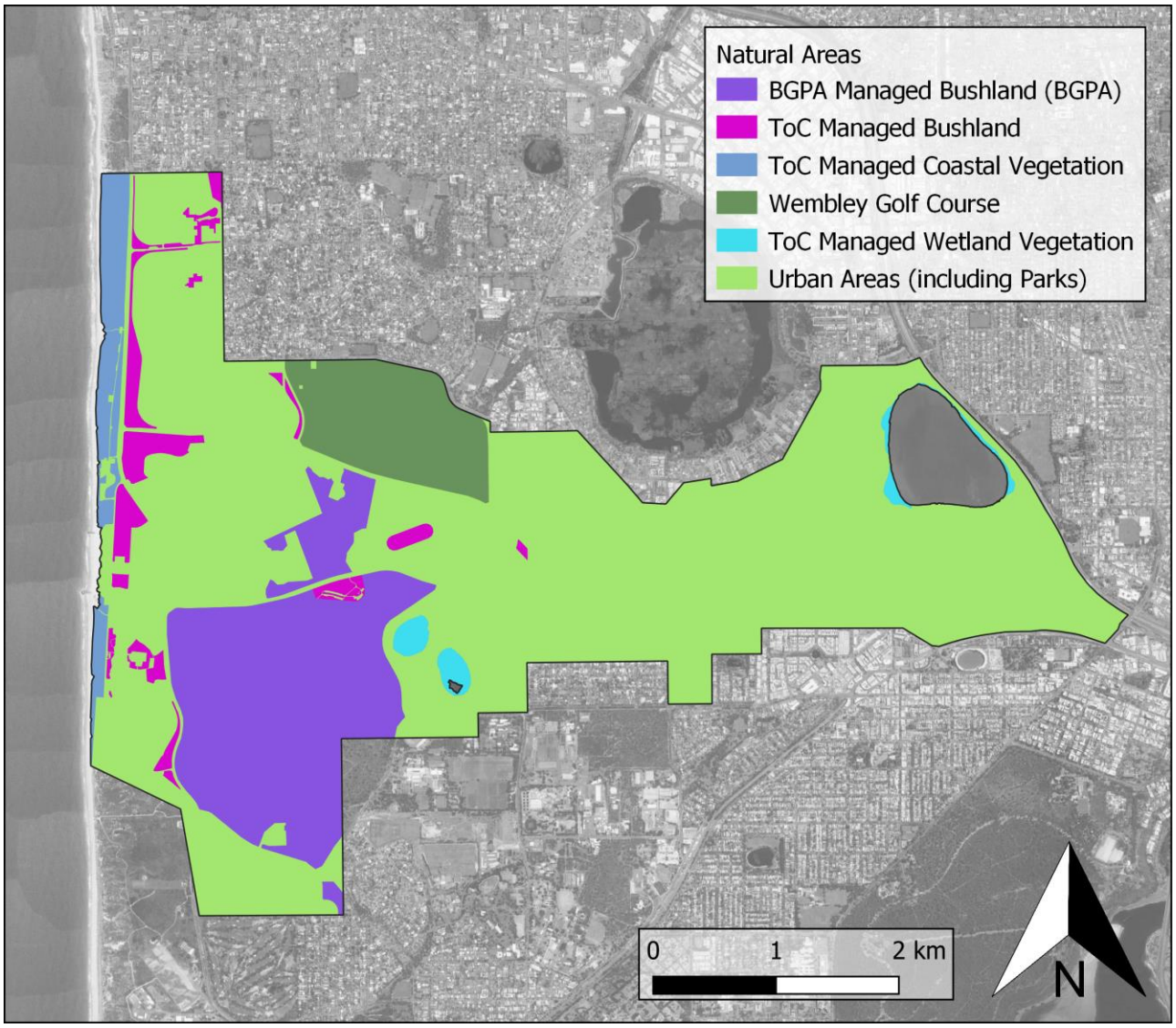



*Figure 29: Vegetation type boundaries in the Town of Cambridge.*

The vegetation type with the greatest proportional canopy cover was Wembley Golf Course (36.8%, Figure 30), followed by ToC Managed Wetland Vegetation (32.9%). ToC Managed Coastal Vegetation had the lowest canopy of 0.7%.

Figure 30 represents canopy cover as a proportion of vegetation type area for each vegetation type category in the Town as a thematic map, with increasing green intensity corresponding to increasing proportional canopy cover. This information also appears in graphical form in Figure 31.

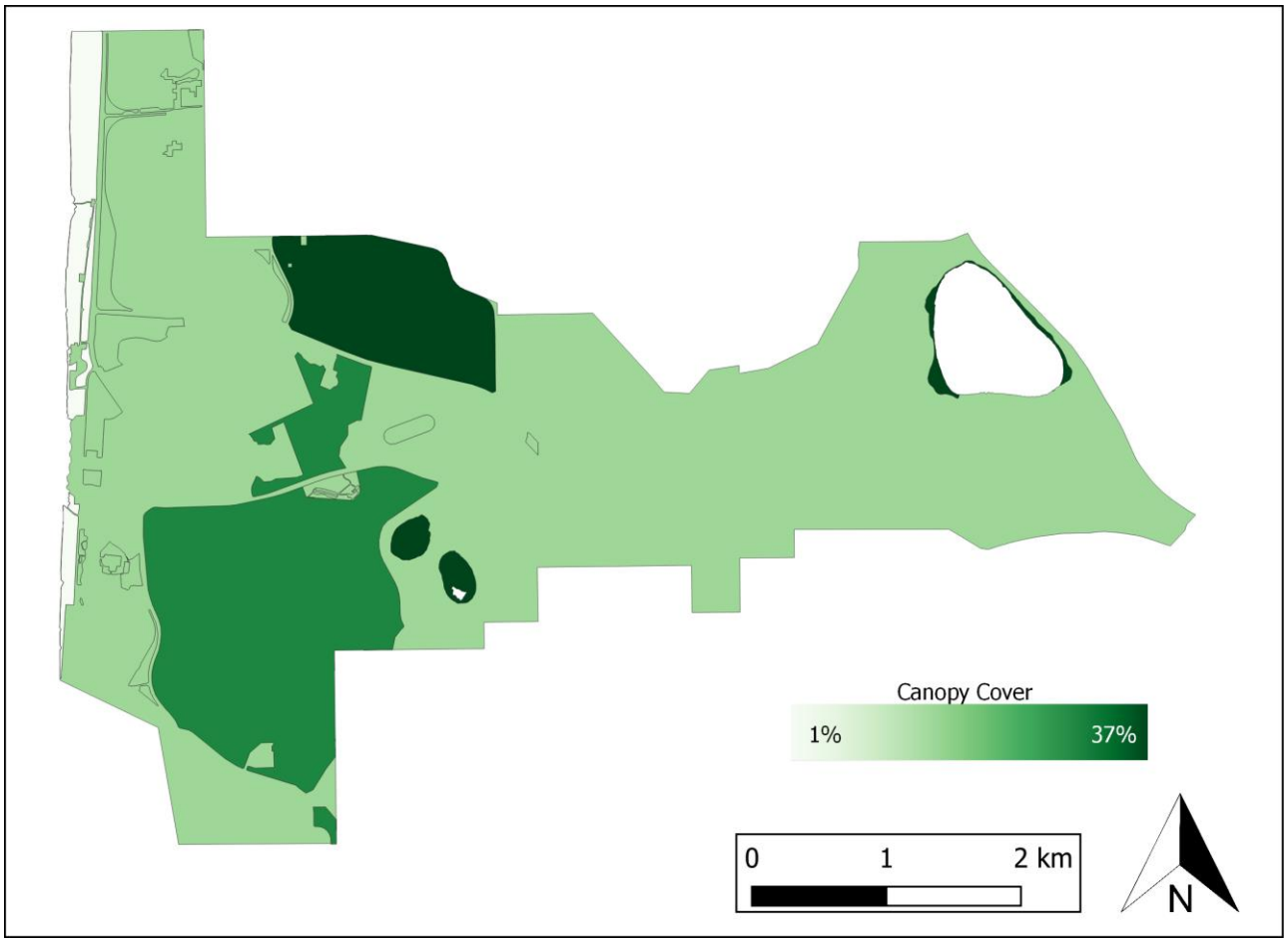



*Figure 30: Thematic map showing canopy cover as a percentage of vegetation type area. The darker green indicates higher relative canopy cover percentage.*

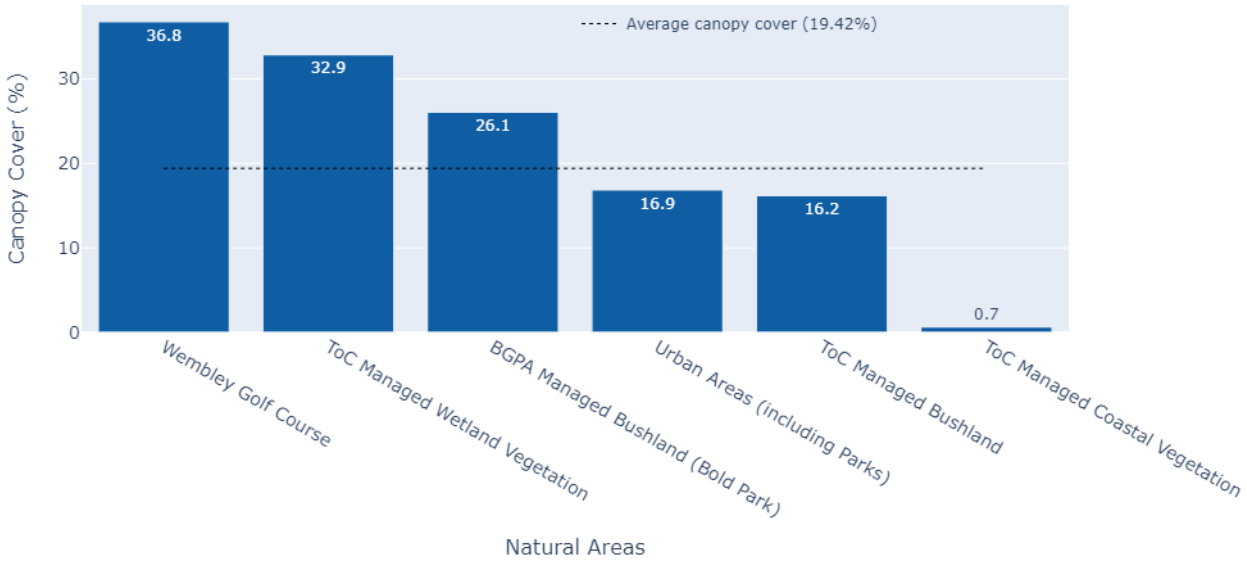



*Figure 31: Canopy cover of each vegetation type in the Town of Cambridge by percentage of total vegetation type area.*

## 3.2.5 Town of Cottesloe

### *3.2.5.1 Council-wide*

Height-stratified vegetation cover was calculated across the entire Town of Cottesloe. The Town is 392.9 ha in size. A total of 127 ha of vegetation across all strata covered 32.3% of the Town's total area (Figure 32 A), with the remaining 67.7% classified as non-vegetation. Over a third (35.6%) of the vegetation was classified in the 0-3m height stratum (Figure 32 B). Another third (32.4%) of the vegetation was classified as 3-10m in height. Turf contributed 21% to the vegetation cover of the Town. The remaining 11% of vegetation was classed in the 10-15m height stratum (5.8%) or >15m in height (5.2%). In total, canopy cover (vegetation >3m in height) comprised 43.4% of vegetation in the City, or 55.2 ha. This is 14% of the Town's total area.

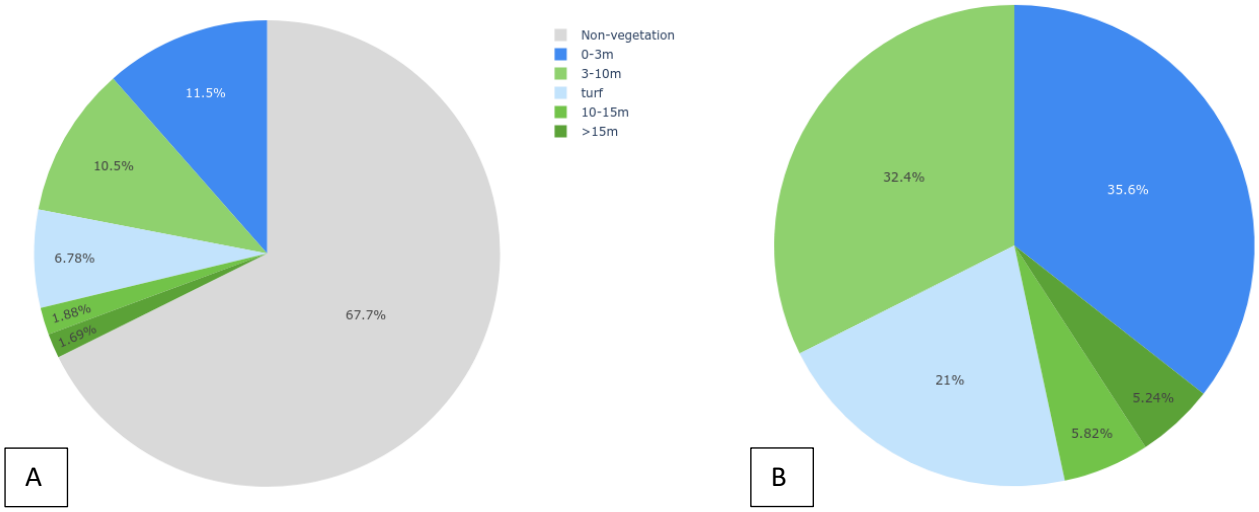



*Figure 32: Land cover by strata (%) (A) and vegetation cover by strata (%) (B) of the Town of Cottesloe.*

### *3.2.5.2 Wards*

Canopy cover statistics were extracted for each ward in the Town of Cottesloe. The east ward had the highest canopy cover as a proportion of total area (18.2%), followed by the central ward (15.3%), the north ward (12.9%), and finally the east ward (11.2%).

Figure 33 represents canopy cover as a proportion of ward area for each ward in the City as a thematic map, with increasing green intensity corresponding to increasing proportional canopy cover. This information also appears in graphical form in Figure 34.

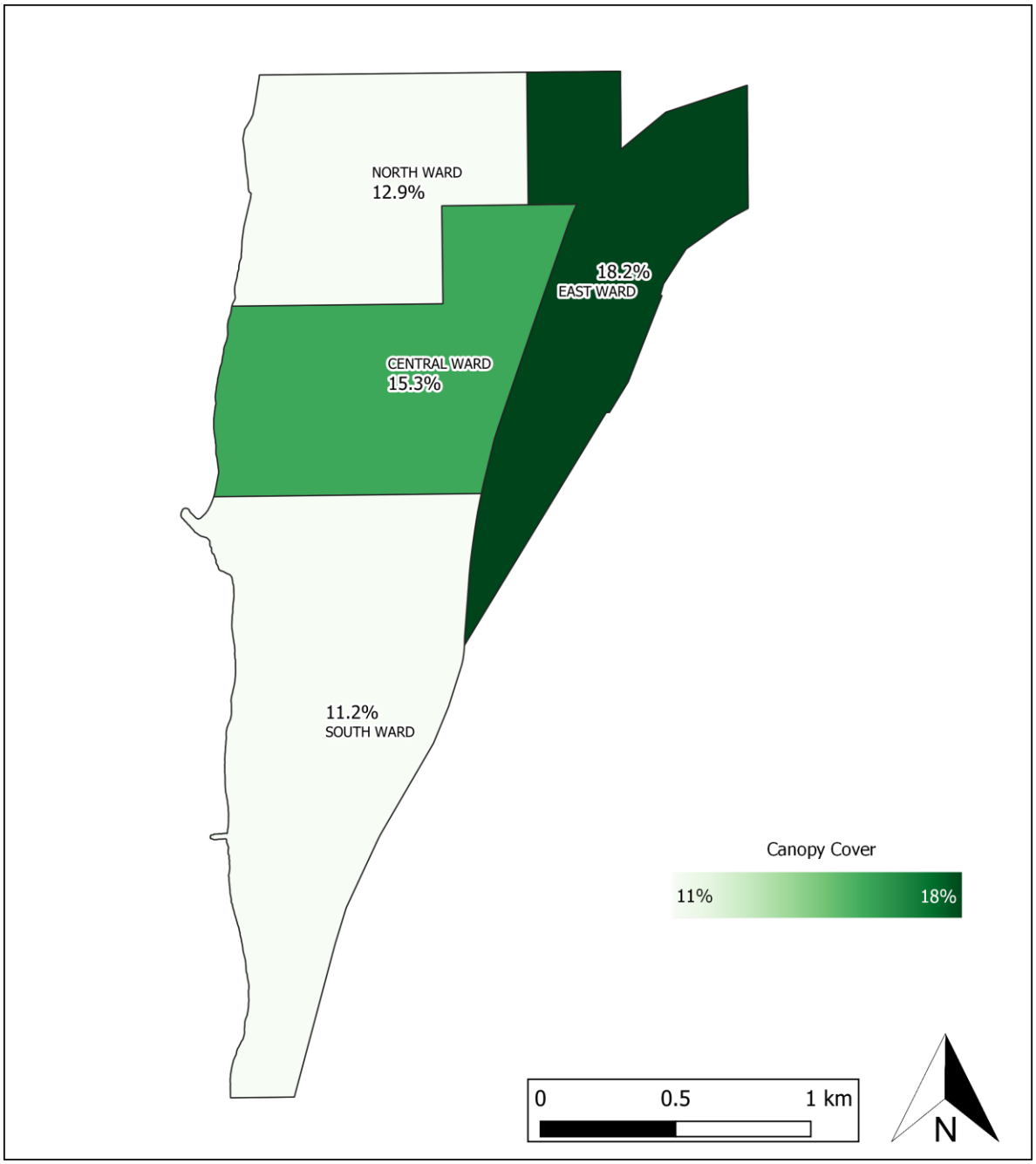



*Figure 33: Thematic map showing canopy cover as a percentage of ward area. The darker green indicates higher relative canopy cover percentage.*

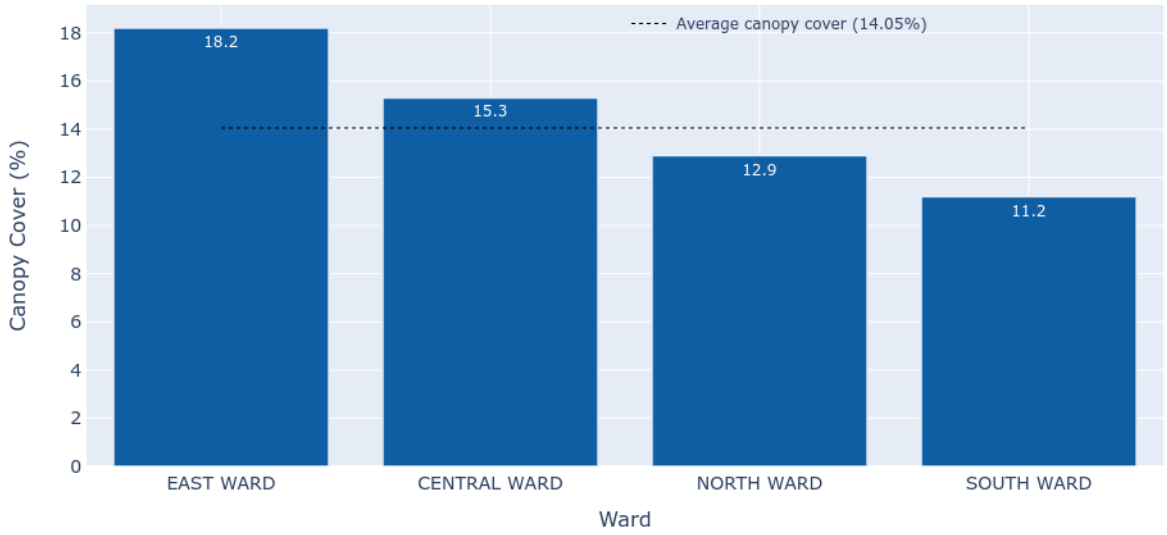



*Figure 34: Canopy cover of each ward in the Town of Cottesloe by percentage of total ward area.*

## 3.3 Vegetation Condition Index

Vegetation Condition Index (VCI) is a quantitative measure of vegetation condition and may be related to the density and colour of foliage. Stress impacting plant function (e.g. photosynthesis) can be detected using VCI, even though it may not be visible to the naked eye. In general, a higher VCI value may indicate higher vegetation condition, while a lower VCI value may indicate lower vegetation condition. VCI also varies independently of condition with factors such as tree species, maturity and season. For this reason, comparisons of VCI values are most reliable when made between trees of the same species. For example, comparing the condition of Norfolk Island Pines between parks is a more robust approach than comparing the overall condition of all trees between parks, which may have a different species profile. The true value of acquiring VCI data over an area with a diverse tree population such as WESROC is to provide a baseline measure of condition. Future acquisitions under similar conditions can then be compared to this baseline to provide an accurate measure of changes in condition at varying spatial scales, down to an individual tree level. In the baseline image it can be used to quickly identify areas of vegetation with low and high vigour.

Figure 35 illustrates the difference in VCI of Norfolk Island Pines in Grant Marine Park in Cottesloe. The RGB imagery in (A) shows a number of Norfolk Island Pines with varying condition. An individual that appears unhealthy is circled in blue, while a comparatively healthier tree is circled in white. The VCI in (B) demonstrates the difference in the trees VCI values; the healthier pine circled in white has higher B=VCI values, as indicated by the green tones of the VCI scale.


*Figure 35: Difference in condition of Norfolk Island Pines in Grant Marine Park in Cottesloe. A) RGB imagery showing two Norfolk Island Pines circled in white and blue. B) The corresponding overlaid VCI illustrates the difference in vigour between the trees; the tree circled in white appears healthier and has a higher VCI compared to the less healthy tree circled in blue, which has a lower VCI.*

# 4 Conclusion and Recommendations

This study provides an accurate assessment of vegetation cover in WESROC in March 2020.

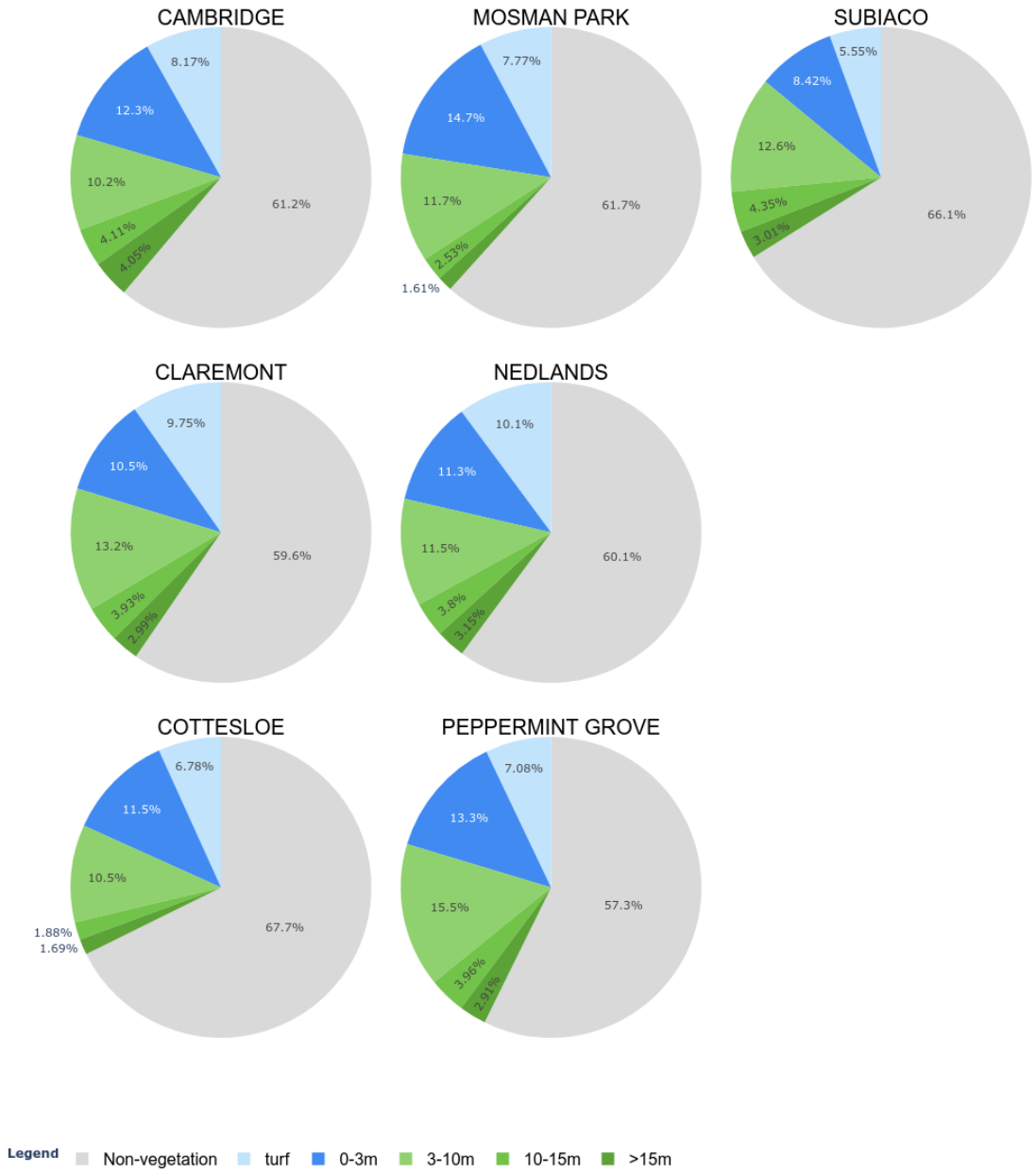
The main findings of this report are:

- At the time of acquisition, on the 10th March 2020, WESROC had a total of 2371.4 ha of vegetation, covering 38.5% of the total area.
- Canopy (vegetation >3m in height) covered 18.3% of the total area, corresponding to 1128.7 ha.
- The majority of canopy fell into the 3-10m height stratum.
- Peppermint Grove had the greatest canopy cover as a proportion of total LGA area (22.4%), followed by Claremont (20.1%) and Subiaco (19.9%). Cottesloe had the lowest (14%) followed by Mosman Park (15.8%).
- The City of Nedlands had a total of 782.6 ha of vegetation across all strata, covering 39.9% of the City's total area. Canopy made up 18.5% of the City's total area.
- Of the City of Nedlands, Karrakatta had the highest canopy cover (26.1%) and Claremont and Swanbourne had the lowest (11.6 and 11.7% respectively).
- The City of Subiaco had a total of 190.3 ha of vegetation across all strata, covering 33.9% of the City's total area. Canopy made up 19.9% of the City's total area.
- Of the City of Subiaco, the South Ward had the highest canopy cover (24.7%) and the East Ward had the lowest (17.5%). Parks & Reserves had the highest canopy cover of all land use categories (34.7%), while Commercial & Municipal had the lowest (7.7%).
- The Town of Cambridge had a total of 857.5 ha of vegetation across all strata, covering 41.1% of the Towns total area. Canopy made up 19.4% of the Town's total area.
- Of the Town of Cambridge, Wembley Downs had the highest canopy cover (35.7%) followed by Floreat (22.7%). Jolimont had the lowest (13%) followed by Wembley (13.9%). Wembley Golf Course (36.8%) and Bold Park (26%) had the highest canopy cover of land use categories, while Mitchell Freeway (9.9%) and Water Corporation (13.4%) had the lowest. Town of Cambridge Managed Coastal Vegetation (0.7%) had the lowest canopy cover of all the natural areas in the Town of Cambridge.
- The Town of Cottesloe had a total of 127 ha of vegetation across all strata, covering 32.3% of the Towns total area. Canopy made up 14% of the Town's total area.
- Of the Town of Cottesloe, the East Ward had the highest canopy cover (18.2%) while the South Ward had the lowest (11.2%).

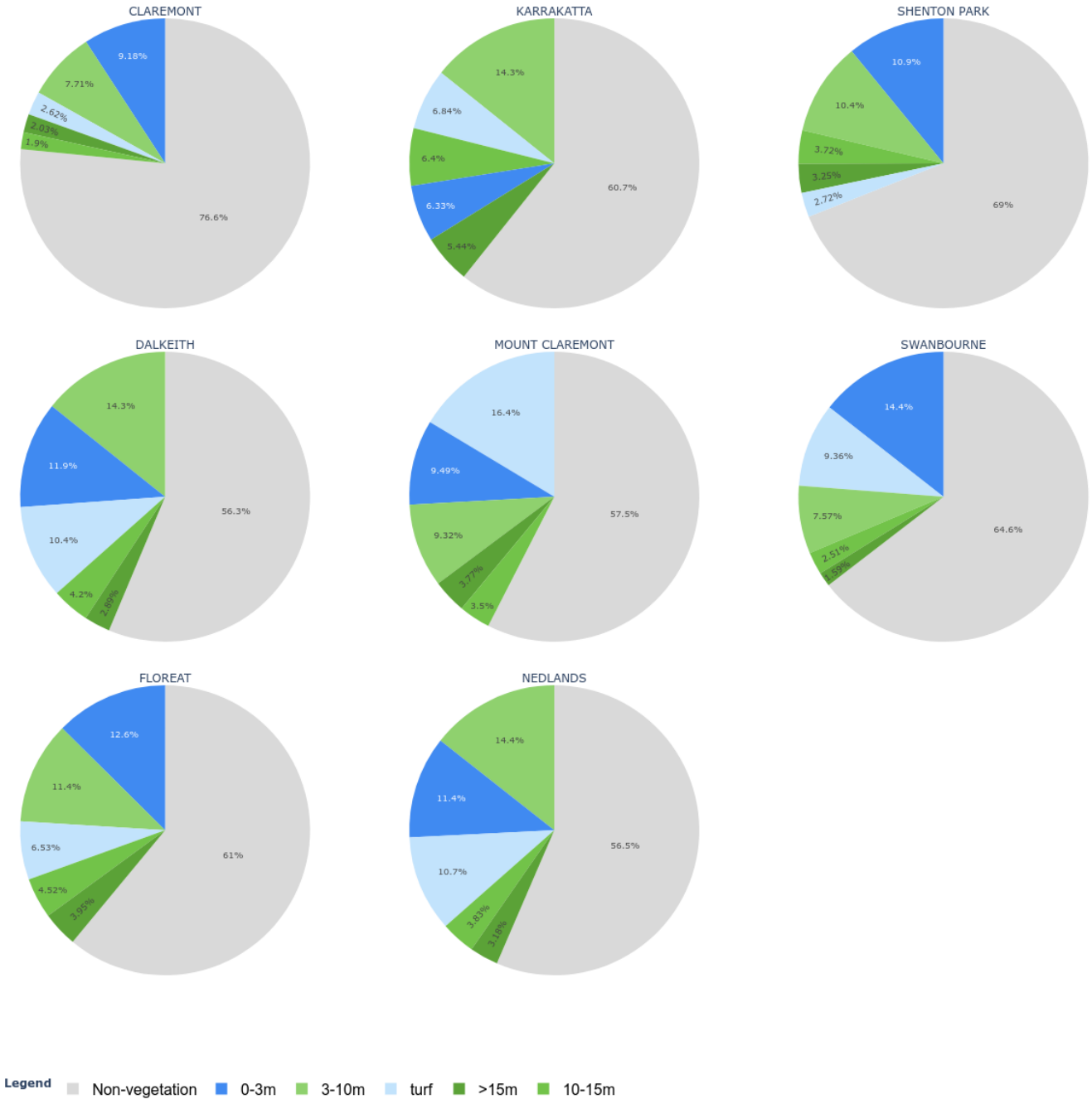
Based on the findings of this analysis, we recommend Airborne multispectral vegetation surveys over the WESROC group of Councils should be conducted on an annual or periodic basis to track changes in vegetation

cover and condition over time and the data used to monitor and set achievable targets for future canopy cover and condition.

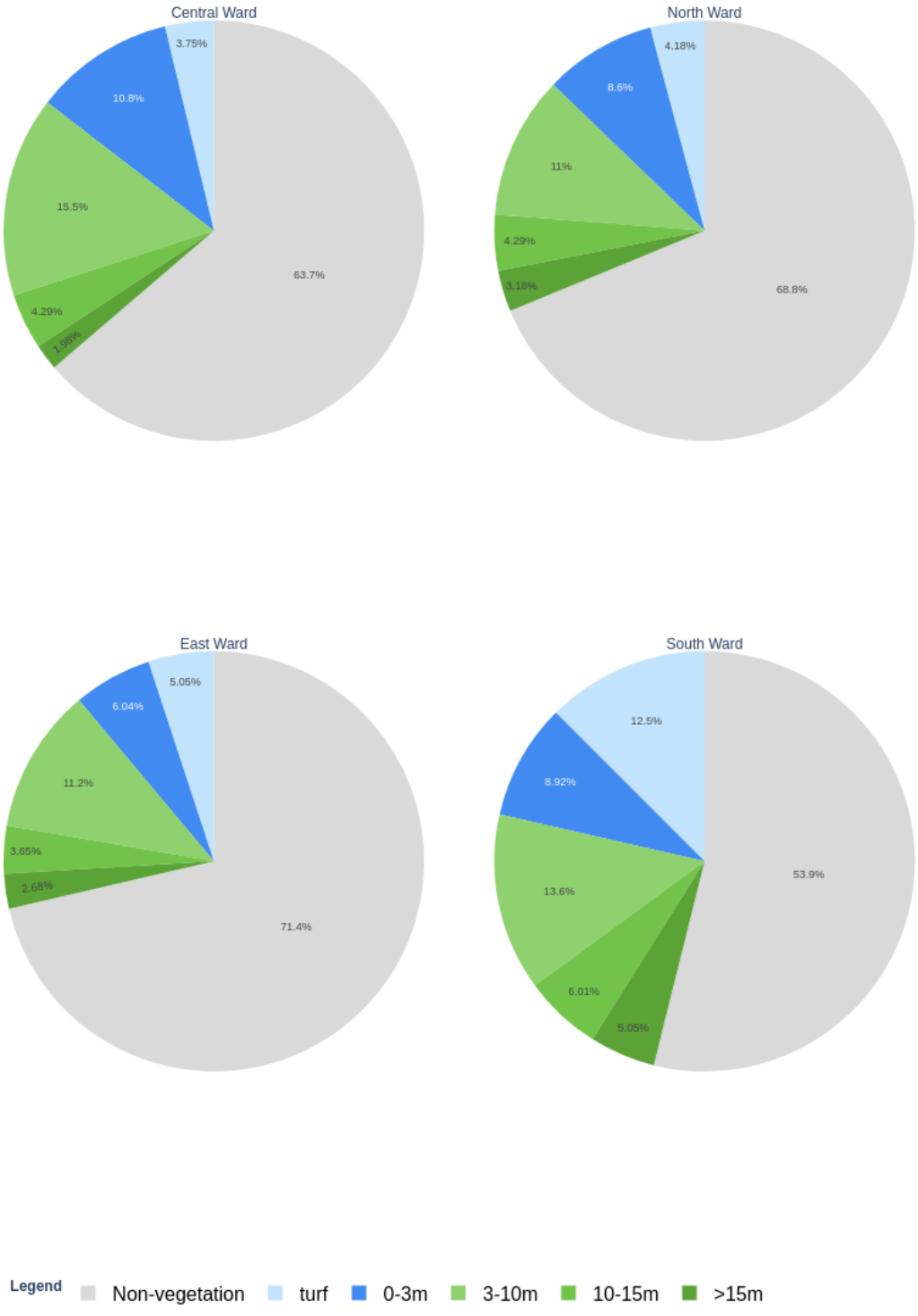
# Appendix A – Vegetation Cover Proportions - WESROC

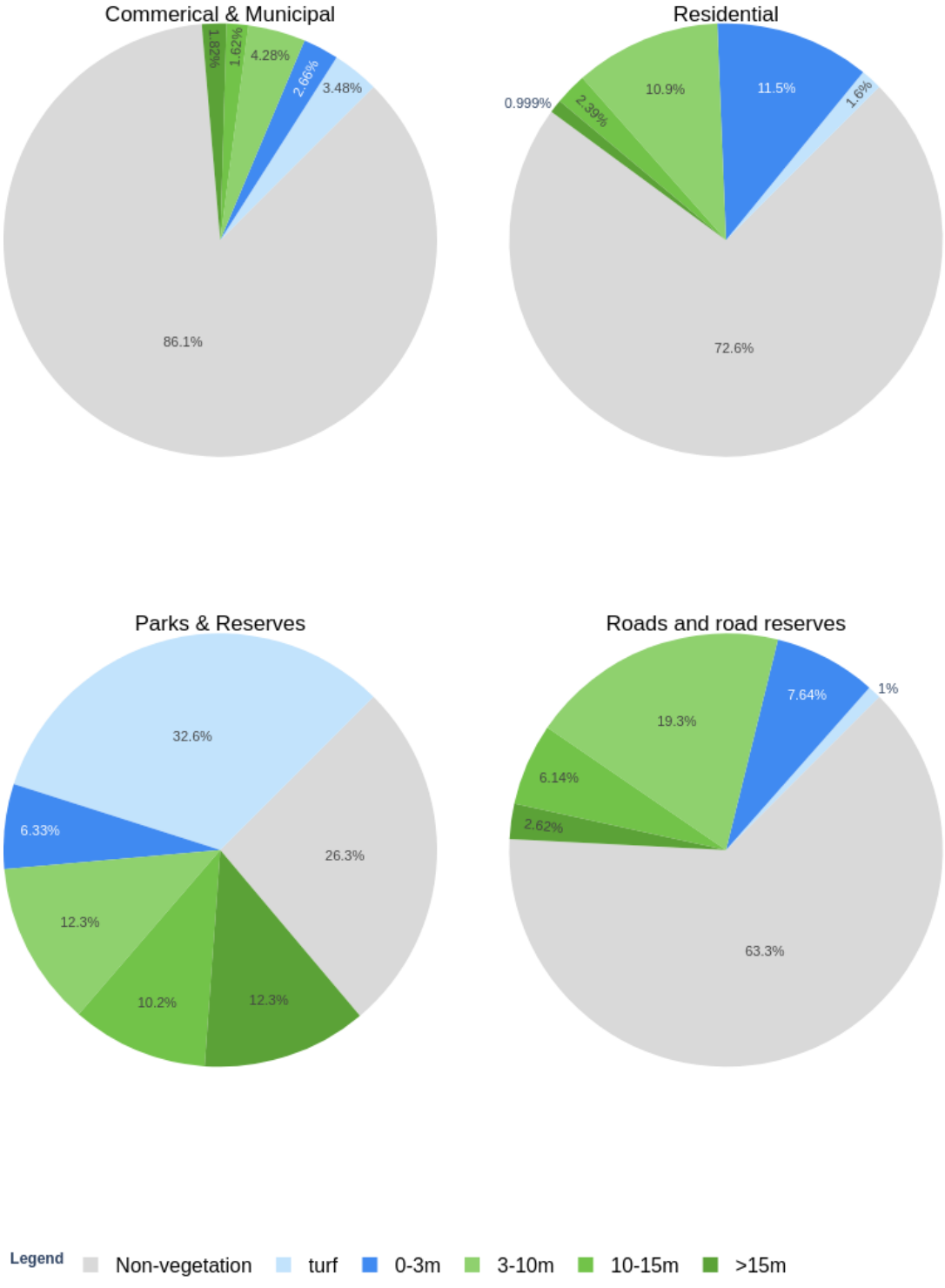


# Appendix B – Vegetation Cover Proportions – City of Nedlands

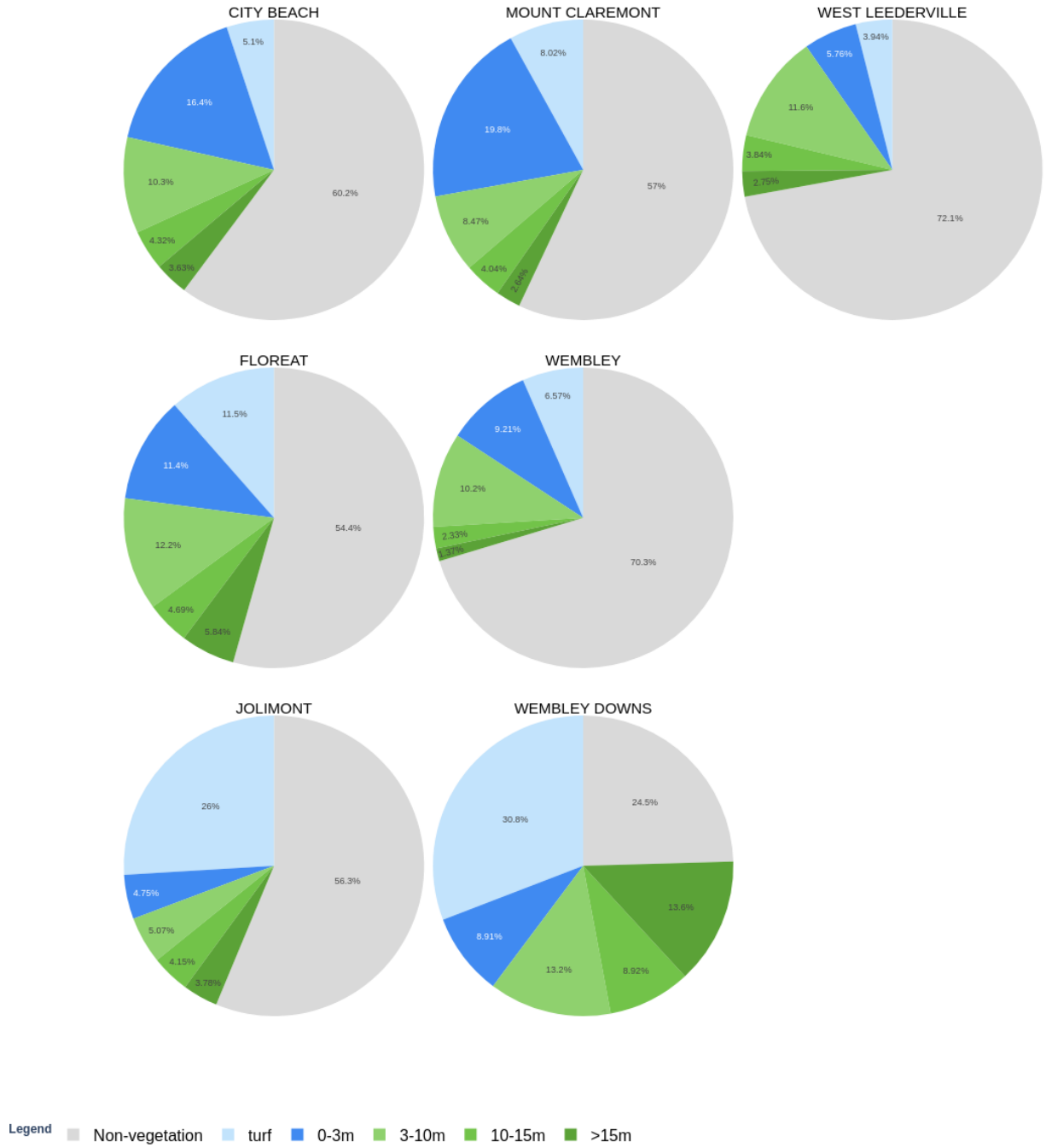


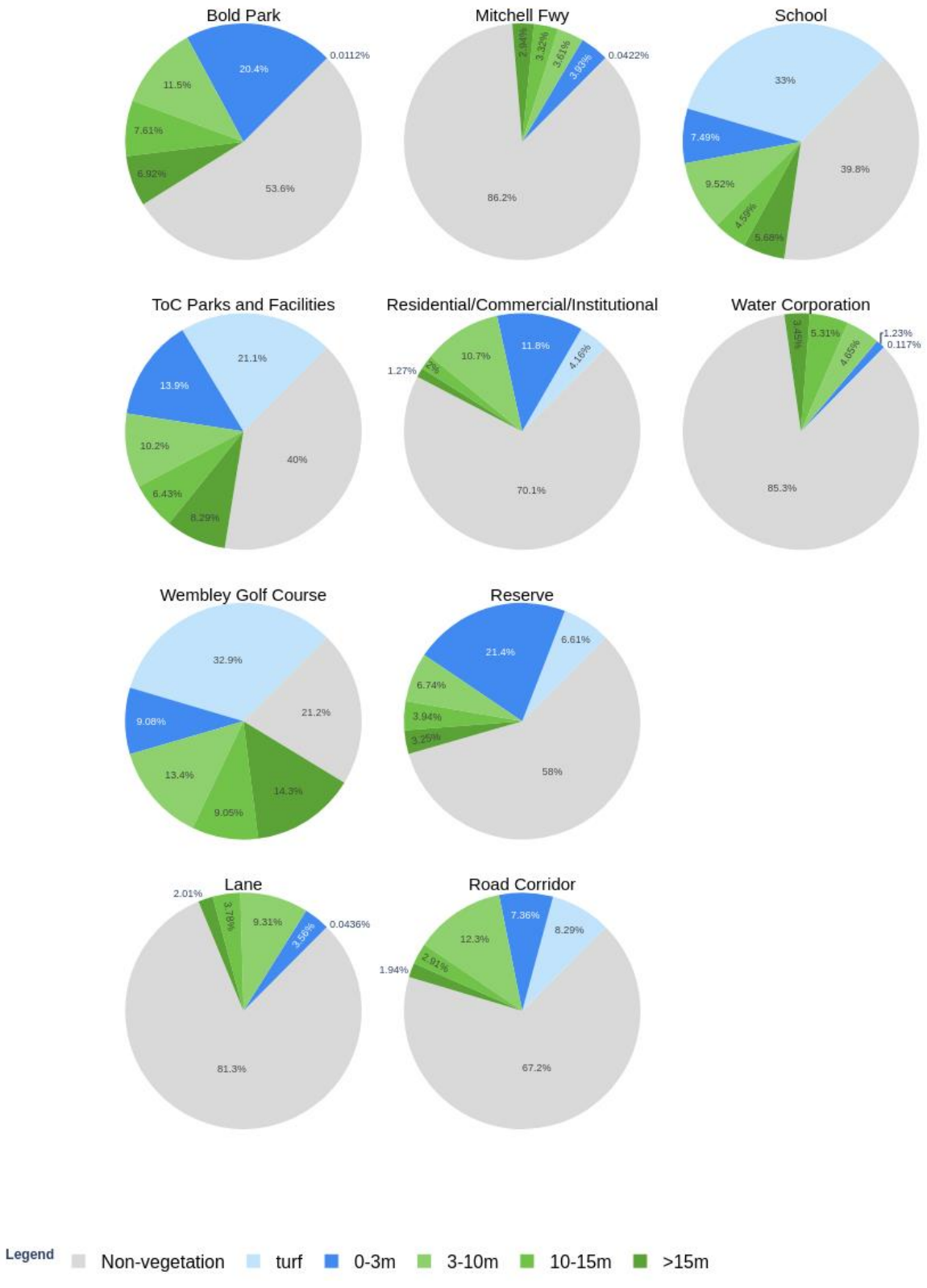
# Appendix C - Vegetation Cover Proportions – City of Subiaco



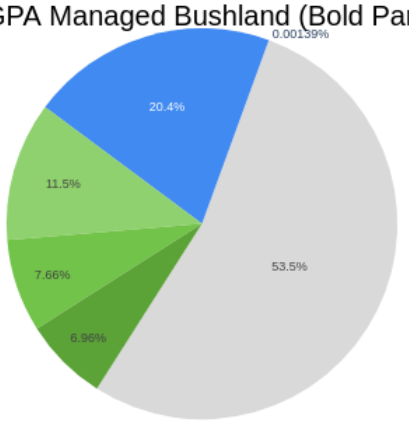

Commerical & Municipal
1.82%
1.62%
4.28%
2.66%
3.48%
86.1%
Residential
0.999%
2.39%
10.9%
11.5%
1.6%
72.6%
Parks & Reserves
32.6%
6.33%
26.3%
12.3%
10.2%
12.3%
Roads and road reserves
1%
7.64%
19.3%
6.14%
2.62%
63.3%
Legend
Non-vegetation
turf
0-3m
3-10m
10-15m
>15m

# Appendix D - Vegetation Cover Proportions – Town of Cambridge

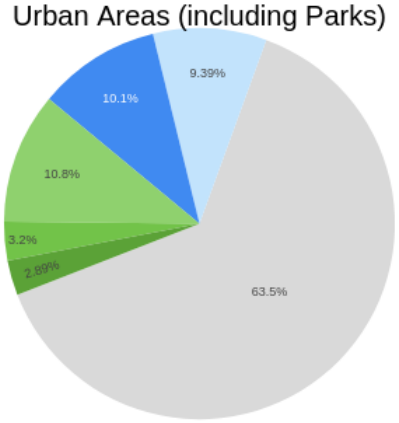



Bold Park
0.0112%
20.4%
11.5%
7.61%
6.92%
53.6%
Mitchell Fwy
2.94%
3.32%
3.61%
3.93%
0.0422%
86.2%
School
33%
7.49%
39.8%
9.52%
4.59%
5.68%
ToC Parks and Facilities
21.1%
13.9%
10.2%
40%
6.43%
8.29%
Residential/Commercial/Institutional
11.8%
10.7%
1.27%
2%
4.16%
70.1%
Water Corporation
3.45%
5.31%
1.23%
0.117%
4.65%
85.3%
Wembley Golf Course
32.9%
9.08%
21.2%
13.4%
14.3%
9.05%
Reserve
21.4%
6.61%
6.74%
3.94%
3.25%
58%
Lane
2.01%
3.78%
9.31%
3.56%
0.0436%
81.3%
Road Corridor
7.36%
8.29%
12.3%
1.94%
2.91%
67.2%
Legend
Non-vegetation
turf
0-3m
3-10m
10-15m
>15m

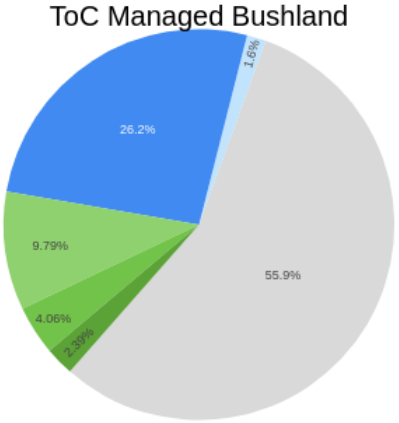
BGPA Managed Bushland (Bold Park)



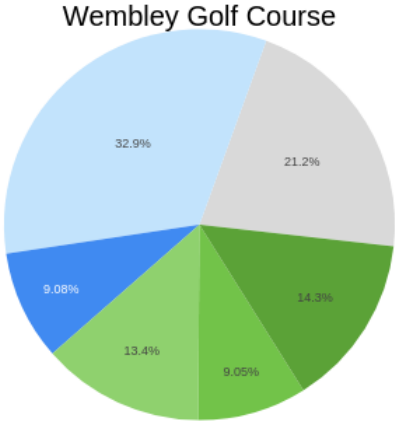

Urban Areas (including Parks)



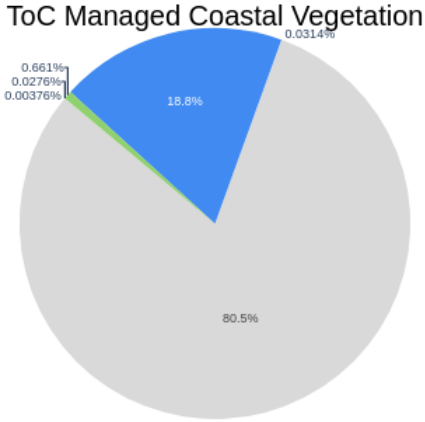

ToC Managed Bushland



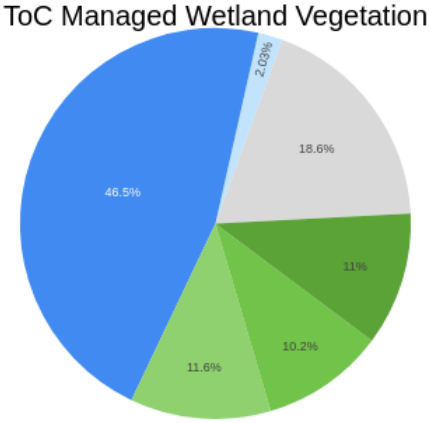

Wembley Golf Course




ToC Managed Coastal Vegetation

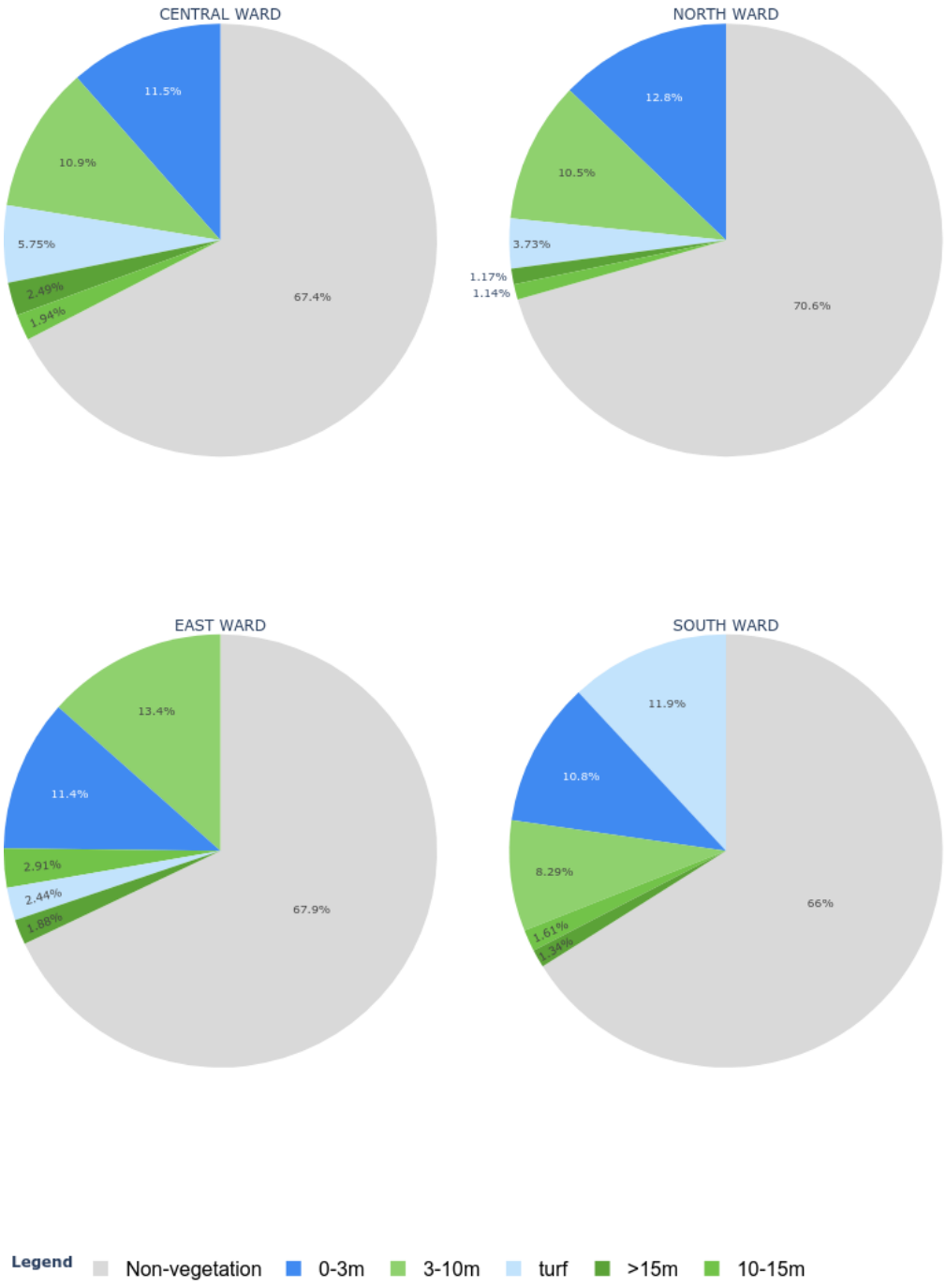



ToC Managed Wetland Vegetation




Legend Non-vegetation turf 0-3m 3-10m 10-15m >15m

# Appendix E - Vegetation Cover Proportions – Town of Cottesloe



# Appendix F – Statistics

WESROC LGAs

| LGA | Area (ha) | Non-vegetation (ha) | Turf (Ha) | 0-3m (Ha) | 3-10m (Ha) | 10-15m (Ha) | >15m (Ha) | Canopy (Ha) | Canopy (%) |
|---|---|---|---|---|---|---|---|---|---|
| **CAMBRIDGE** | 2213.75 | 1354.17 | 180.87 | 271.91 | 226.11 | 90.96 | 89.72 | 406.79 | 18.4 |
| **CLAREMONT** | 496.94 | 296.09 | 48.45 | 52.36 | 65.67 | 19.53 | 14.85 | 100.05 | 20.1 |
| **COTTESLOE** | 392.91 | 265.89 | 26.64 | 45.17 | 41.15 | 7.39 | 6.66 | 55.20 | 14.0 |
| **MOSMAN PARK** | 431.97 | 266.51 | 33.57 | 63.53 | 50.48 | 10.92 | 6.96 | 68.36 | 15.8 |
| **NEDLANDS** | 1961.21 | 1178.60 | 199.02 | 220.98 | 226.48 | 74.43 | 61.70 | 362.61 | 18.5 |
| **PEPPERMINT GROVE** | 106.40 | 60.95 | 7.54 | 14.11 | 16.50 | 4.21 | 3.10 | 23.80 | 22.4 |
| **SUBIACO** | 561.74 | 371.34 | 31.19 | 47.33 | 70.55 | 24.45 | 16.89 | 111.88 | 19.9 |

City of Nedlands Suburbs

| Suburb | Area (ha) | Non-vegetation (ha) | Turf (Ha) | 0-3m (Ha) | 3-10m (Ha) | 10-15m (Ha) | >15m (Ha) | Canopy (Ha) | Canopy (%) |
|---|---|---|---|---|---|---|---|---|---|
| **CLAREMONT** | 5.49 | 4.21 | 0.14 | 0.50 | 0.42 | 0.10 | 0.11 | 0.64 | 11.6 |
| **DALKEITH** | 295.88 | 166.68 | 30.90 | 35.14 | 42.18 | 12.44 | 8.54 | 63.17 | 21.3 |
| **FLOREAT** | 54.89 | 33.48 | 3.58 | 6.89 | 6.28 | 2.48 | 2.17 | 10.93 | 19.9 |
| **KARRAKATTA** | 179.45 | 108.97 | 12.28 | 11.37 | 25.57 | 11.49 | 9.77 | 46.83 | 26.1 |
| **MOUNT CLAREMONT** | 353.37 | 203.27 | 57.96 | 33.52 | 32.94 | 12.38 | 13.30 | 58.62 | 16.6 |
| **NEDLANDS** | 478.33 | 270.17 | 51.20 | 54.66 | 68.75 | 18.32 | 15.22 | 102.30 | 21.4 |
| **SHENTON PARK** | 189.84 | 130.94 | 5.17 | 20.72 | 19.77 | 7.06 | 6.18 | 33.01 | 17.4 |
| **SWANBOURNE** | 403.76 | 260.69 | 37.78 | 58.18 | 30.56 | 10.15 | 6.41 | 47.11 | 11.7 |

City of Subiaco Land Use Categories

| Land Use Category | Area (ha) | Non-vegetation (ha) | Turf (Ha) | 0-3m (Ha) | 3-10m (Ha) | 10-15m (Ha) | >15m (Ha) | Canopy (Ha) | Canopy (%) |
|---|---|---|---|---|---|---|---|---|---|
| **Commercial & Municipal** | 83.18 | 71.64 | 2.89 | 2.21 | 3.56 | 1.34 | 1.52 | 6.42 | 7.7 |
| **Parks & Reserves** | 69.86 | 18.41 | 22.76 | 4.42 | 8.57 | 7.11 | 8.59 | 24.27 | 34.7 |
| **Residential** | 242.68 | 176.11 | 3.87 | 28.00 | 26.43 | 5.79 | 2.42 | 34.64 | 14.3 |
| **Roads and Road Reserves** | 165.70 | 104.96 | 1.66 | 12.67 | 31.96 | 10.17 | 4.34 | 46.47 | 28 |

City of Subiaco Wards

| Wards | Area (ha) | Non-vegetation (ha) | Turf (Ha) | 0-3m (Ha) | 3-10m (Ha) | 10-15m (Ha) | >15m (Ha) | Canopy (Ha) | Canopy (%) |
|---|---|---|---|---|---|---|---|---|---|
| **Central Ward** | 140.24 | 89.37 | 5.26 | 15.14 | 21.68 | 6.01 | 2.78 | 30.47 | 21.7 |
| **East Ward** | 168.73 | 120.42 | 8.52 | 10.19 | 18.92 | 6.16 | 4.53 | 29.60 | 17.5 |
| **North Ward** | 169.90 | 116.83 | 7.10 | 14.62 | 18.67 | 7.29 | 5.40 | 31.35 | 18.5 |
| **South Ward** | 82.55 | 44.49 | 10.32 | 7.36 | 11.26 | 4.96 | 4.17 | 20.38 | 24.7 |

Town of Cambridge Suburbs

| Suburb | Area (ha) | Non-vegetation (ha) | Turf (Ha) | 0-3m (Ha) | 3-10m (Ha) | 10-15m (Ha) | >15m (Ha) | Canopy (Ha) | Canopy (%) |
|---|---|---|---|---|---|---|---|---|---|
| **CITY BEACH** | 949.45 | 571.64 | 48.45 | 155.79 | 98.09 | 41.03 | 34.45 | 173.58 | 18.3 |
| **FLOREAT** | 419.80 | 228.32 | 48.31 | 47.92 | 51.04 | 19.70 | 24.52 | 95.26 | 22.7 |
| **JOLIMONT** | 30.21 | 17.01 | 7.85 | 1.44 | 1.53 | 1.25 | 1.14 | 3.93 | 13 |
| **MOUNT CLAREMONT** | 78.53 | 44.77 | 6.30 | 15.56 | 6.65 | 3.17 | 2.07 | 11.90 | 15.2 |
| **WEMBLEY** | 324.11 | 227.97 | 21.30 | 29.86 | 32.96 | 7.56 | 4.45 | 44.97 | 13.9 |
| **WEMBLEY DOWNS** | 138.14 | 33.91 | 42.61 | 12.31 | 18.23 | 12.32 | 18.76 | 49.31 | 35.7 |
| **WEST LEEDERVILLE** | 146.42 | 105.60 | 5.76 | 8.44 | 16.98 | 5.62 | 4.02 | 26.62 | 18.2 |

Town of Cambridge Natural Areas

| Natural Area | Area (ha) | Non-vegetation (ha) | Turf (Ha) | 0-3m (Ha) | 3-10m (Ha) | 10-15m (Ha) | >15m (Ha) | Canopy (Ha) | Canopy (%) |
|---|---|---|---|---|---|---|---|---|---|
| **BGPA Managed Bushland (Bold Park)** | 359.04 | 192.01 | 0.01 | 73.20 | 41.32 | 27.51 | 25.00 | 93.83 | 26.1 |
| **ToC Managed Bushland** | 67.99 | 38.02 | 1.08 | 17.84 | 6.66 | 2.76 | 1.62 | 11.04 | 16.2 |
| **ToC Managed Coastal Vegetation** | 59.80 | 48.14 | 0.02 | 11.23 | 0.40 | 0.02 | 0.00 | 0.41 | 0.7 |
| **Urban Areas (including Parks)** | 1455.58 | 924.70 | 136.69 | 147.74 | 157.70 | 46.62 | 42.14 | 246.45 | 16.9 |
| **Wembley Golf Course** | 129.15 | 27.41 | 42.52 | 11.72 | 17.36 | 11.69 | 18.45 | 47.49 | 36.8 |
| **ToC Managed Wetland Vegetation** | 22.09 | 4.11 | 0.45 | 10.26 | 2.57 | 2.25 | 2.44 | 7.26 | 32.9 |

Town of Cambridge Land Use Areas

| Land Use Area | Area (ha) | Non-vegetation (ha) | Turf (Ha) | 0-3m (Ha) | 3-10m (Ha) | 10-15m (Ha) | >15m (Ha) | Canopy (Ha) | Canopy (%) |
|---|---|---|---|---|---|---|---|---|---|
| **Bold Park** | 361.20 | 193.64 | 0.04 | 73.64 | 41.38 | 27.50 | 25.00 | 93.88 | 26 |
| **ToC Parks and Facilities** | 252.62 | 101.15 | 53.40 | 35.23 | 25.65 | 16.24 | 20.94 | 62.83 | 24.9 |
| **Wembley Golf Course** | 129.15 | 27.41 | 42.52 | 11.72 | 17.36 | 11.69 | 18.45 | 47.49 | 36.8 |
| **Lane** | 10.48 | 8.52 | 0.00 | 0.37 | 0.98 | 0.40 | 0.21 | 1.58 | 15.1 |
| **Mitchell Fwy** | 14.54 | 12.53 | 0.01 | 0.57 | 0.53 | 0.48 | 0.43 | 1.44 | 9.9 |
| **Residential/Commercial/Institutional** | 731.01 | 512.75 | 30.39 | 85.98 | 77.94 | 14.64 | 9.31 | 101.89 | 13.9 |
| **Reserve** | 152.65 | 88.56 | 10.08 | 32.74 | 10.28 | 6.02 | 4.96 | 21.26 | 13.9 |
| **Road Corridor** | 380.59 | 255.59 | 31.55 | 27.99 | 46.99 | 11.07 | 7.39 | 65.45 | 17.2 |
| **School** | 38.12 | 15.16 | 12.56 | 2.86 | 3.63 | 1.75 | 2.17 | 7.54 | 19.8 |
| **Water Corporation** | 16.33 | 13.92 | 0.02 | 0.20 | 0.76 | 0.87 | 0.56 | 2.19 | 13.4 |

Town of Cottesloe Wards

| Wards | Area (ha) | Non-vegetation (ha) | Turf (Ha) | 0-3m (Ha) | 3-10m (Ha) | 10-15m (Ha) | >15m (Ha) | Canopy (Ha) | Canopy (%) |
|---|---|---|---|---|---|---|---|---|---|
| **CENTRAL WARD** | 90.98 | 61.34 | 5.23 | 10.48 | 9.91 | 1.76 | 2.26 | 13.94 | 15.3 |
| **EAST WARD** | 86.75 | 58.94 | 2.12 | 9.87 | 11.66 | 2.53 | 1.63 | 15.82 | 18.2 |
| **NORTH WARD** | 77.51 | 54.70 | 2.89 | 9.95 | 8.17 | 0.89 | 0.91 | 9.97 | 12.9 |
| **SOUTH WARD** | 137.66 | 90.92 | 16.39 | 14.88 | 11.41 | 2.21 | 1.85 | 15.47 | 11.2 |