



Precision Airborne Measurement and Monitoring of Urban Forest Cover and Condition

Western Suburbs Regional Organisation of Councils

Report No. J20462

27th July 2020

Company Name: ArborCarbon Pty Ltd

ACN: 145 766 472

ABN: 62 145 766 472

Address: 1 City Farm Place, East Perth WA 6004

Phone Number: +61 8 9467 9876


Name and Position of Authorised Signatory: Dr Paul Barber | Managing Director

Contact Phone Number: +61 419 216 229

Website: www.arborcarbon.com.au

DOCUMENT QUALITY ASSURANCE

Prepared by	Reviewed by
Briony Williams	Dr Paul Barber

Approved & Released by	Position	Approval Signature
Dr Paul Barber	Managing Director	

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

DISCLAIMER

ArborCarbon Pty Ltd has prepared this document using data and information supplied from WESROC and other individuals and organisations, who have been referred to in this document.

This document is confidential and intended to be read in its entirety, and sections or parts of the document should therefore not be read and relied on out of context. The sole use of this document is for WESROC only for which it was prepared.

While the information contained in this report has been formulated with due care, the author(s) and ArborCarbon Pty Ltd take no responsibility for any person acting or relying on the information contained in this report, and disclaim any liability for any error, omission, loss or other consequence which may arise from any person acting or relying on anything contained in this report. This report is the property of ArborCarbon Pty Ltd and should not be altered or reproduced without the written permission of ArborCarbon Pty Ltd.

Any conclusion and/or recommendation contained in this document reflect the professional opinion of ArborCarbon Pty Ltd and the author(s) using the data and information supplied. ArborCarbon Pty Ltd has used reasonable care and professional judgement in its interpretation and analysis of data in accordance with the contracted Scope of Works.

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 the Town of Cottesloe'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 on 10 March 2020 using the ArborCam®, a camera designed by ArborCarbon specifically for monitoring vegetation cover and condition. The data was analysed to review vegetation cover across WESROC, including the Town of Cottesloe and its wards.

The main findings of this report are:

- 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 Town of Cottesloe 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

Executive Summary	3
1 Introduction	6
2 Methods	7
2.1 Acquisition of high-resolution airborne imagery	7
3 Results and Discussion	8
3.1 Datasets	8
3.2 Analysis of vegetation cover	14
3.2.1 Town of Cottesloe	14
3.3 Vegetation Condition Index	16
4 Conclusion and Recommendations	18
Appendix A - Vegetation Cover Proportions – Town of Cottesloe	20
Appendix F – Statistics	21

List of Figures

Figure 1: High-resolution RGB imagery of WESROC.	8
Figure 2: False colour composite of WESROC showing vegetation (red pixels).....	9
Figure 3: Height-stratified vegetation dataset derived with each strata displayed in a different colour.	10
Figure 4: Radiometrically corrected thermal orthomosaic land surface temperature of WESROC ranging from 20°C (blue) to 40°C (red).	11
Figure 5: Vegetation Condition Index (VCI) across WESROC, ranging from low (red) to high (purple).	12
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).	14
Figure 32: Land cover by strata (%) (A) and vegetation cover by strata (%) (B) of the Town of Cottesloe. ...	14
Figure 33: Thematic map showing canopy cover as a percentage of ward area. The darker green indicates higher relative canopy cover percentage.....	15
Figure 34: Canopy cover of each ward in the Town of Cottesloe by percentage of total ward area.	16
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.	17

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 the Town of Cottesloe'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 over the boundary with cloudless conditions between 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 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).

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.

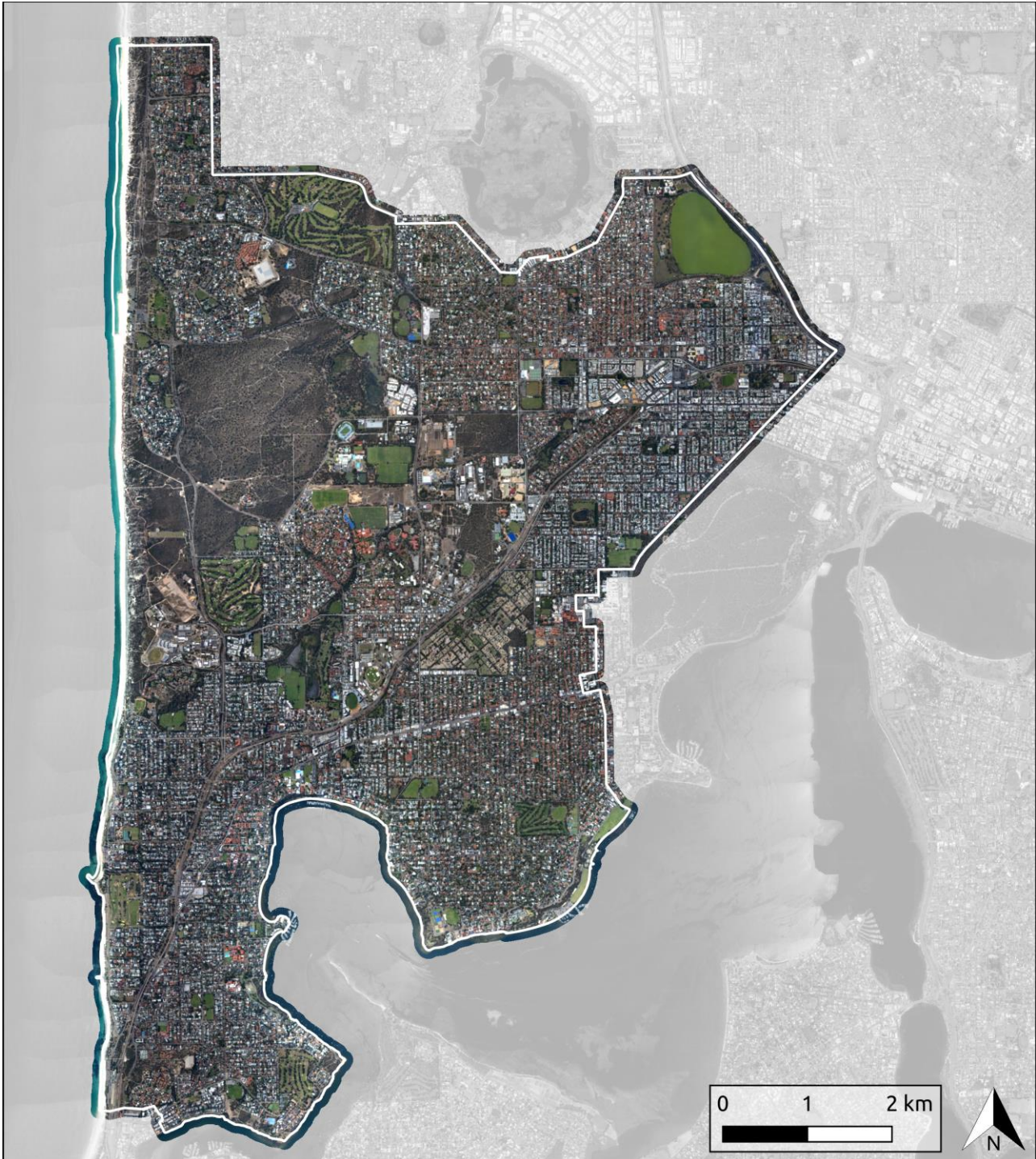


Figure 1: High-resolution RGB imagery of WESROC.

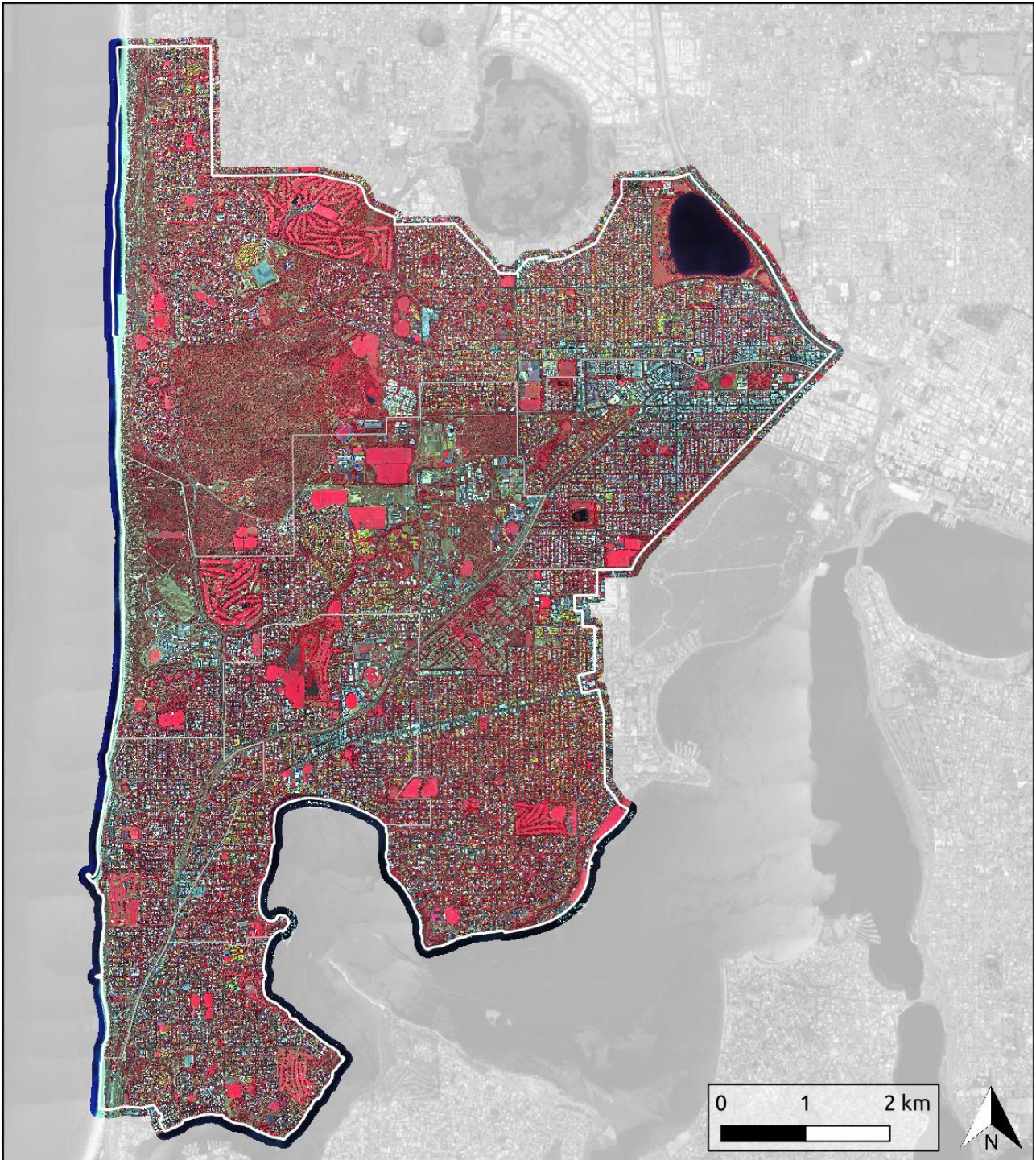


Figure 2: False colour composite of WESROC showing vegetation (red pixels).

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.

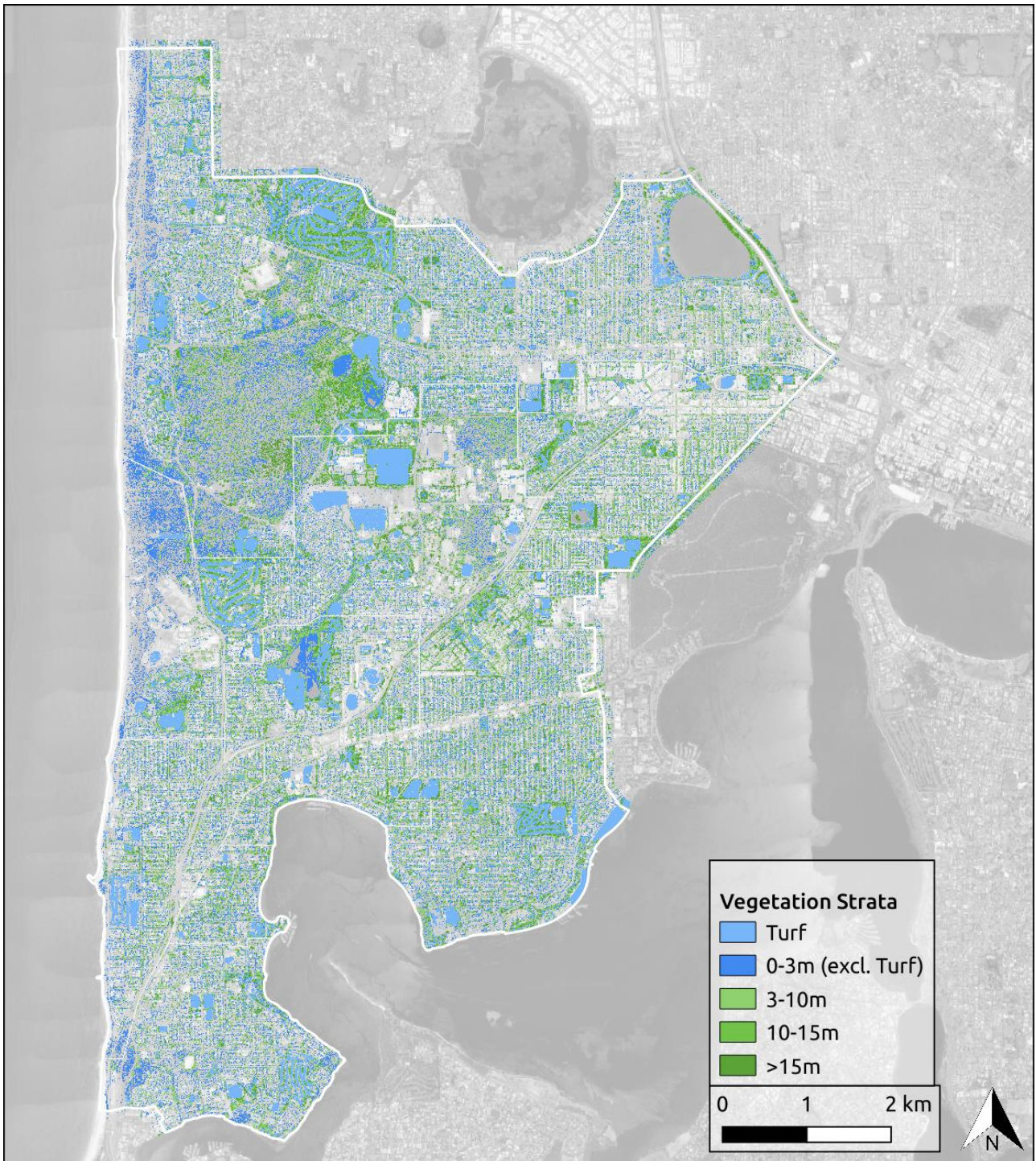


Figure 3: Height-stratified vegetation dataset derived with each strata displayed in a different colour.

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.

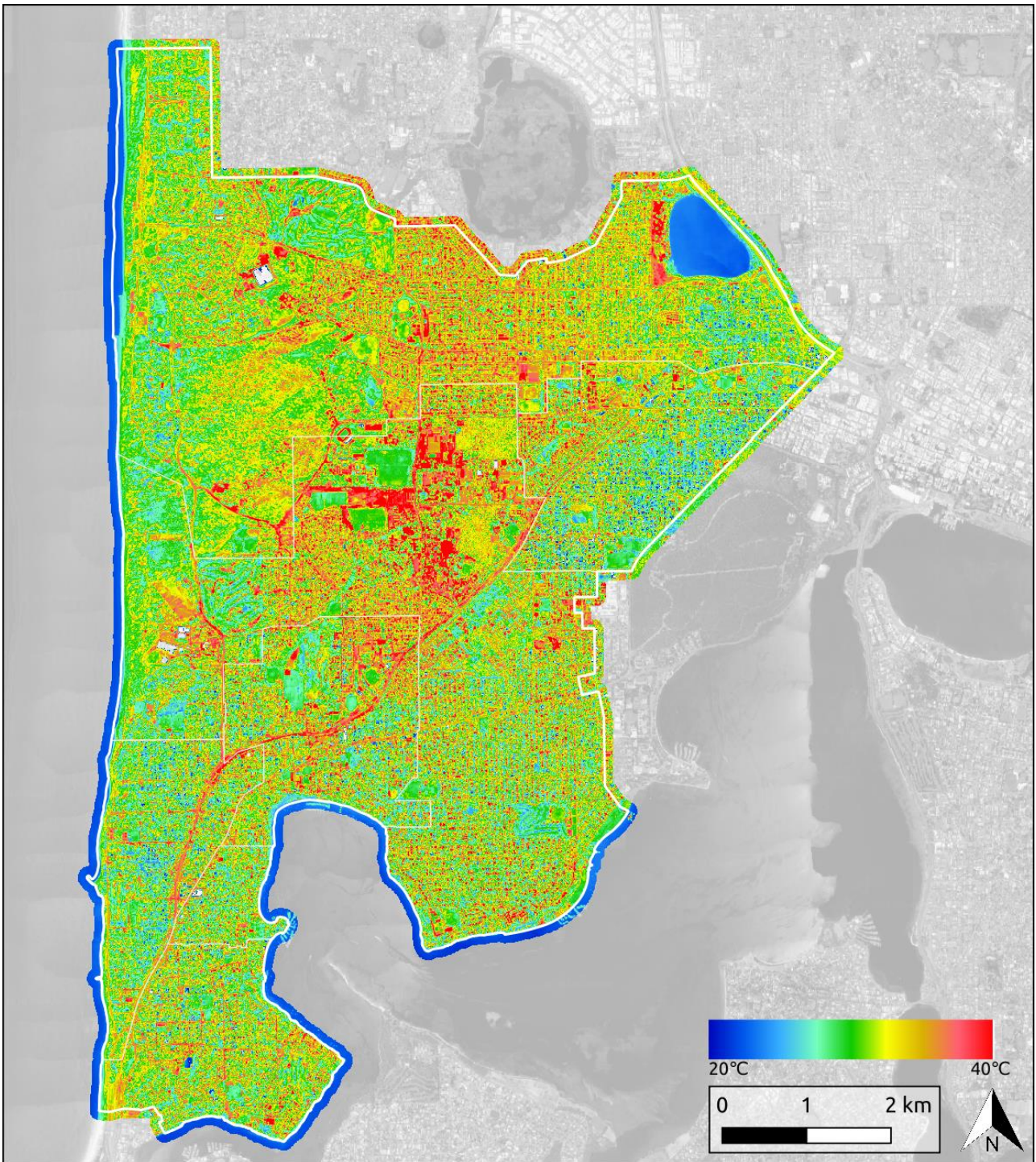


Figure 4: Radiometrically corrected thermal orthomosaic land surface temperature of WESROC ranging from 20°C (blue) to 40°C (red).

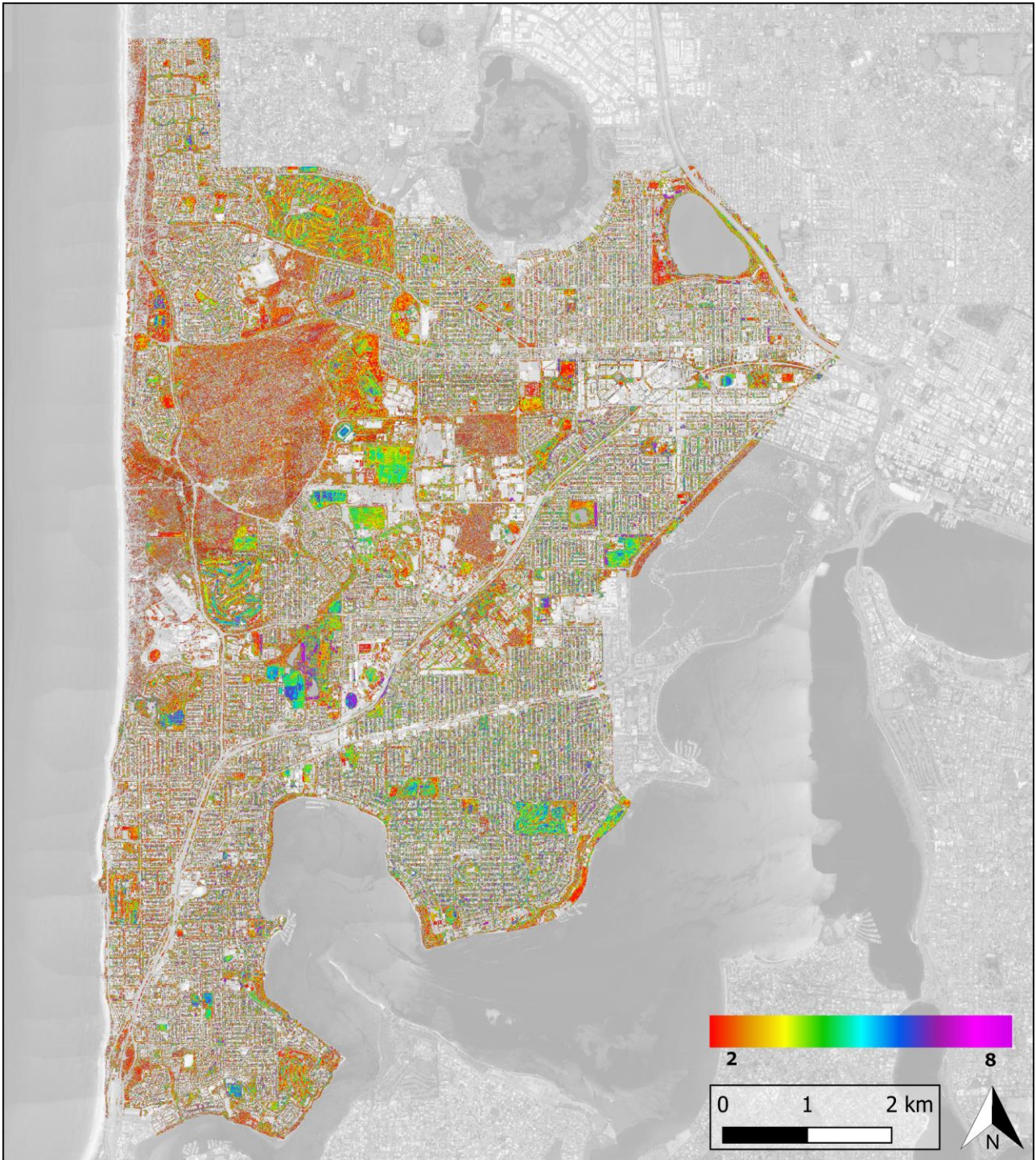


Figure 5: Vegetation Condition Index (VCI) across WESROC, ranging from low (red) to high (purple).

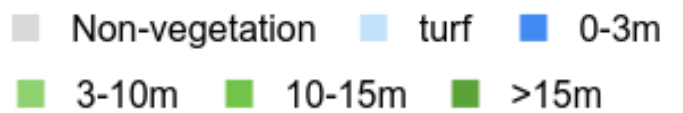
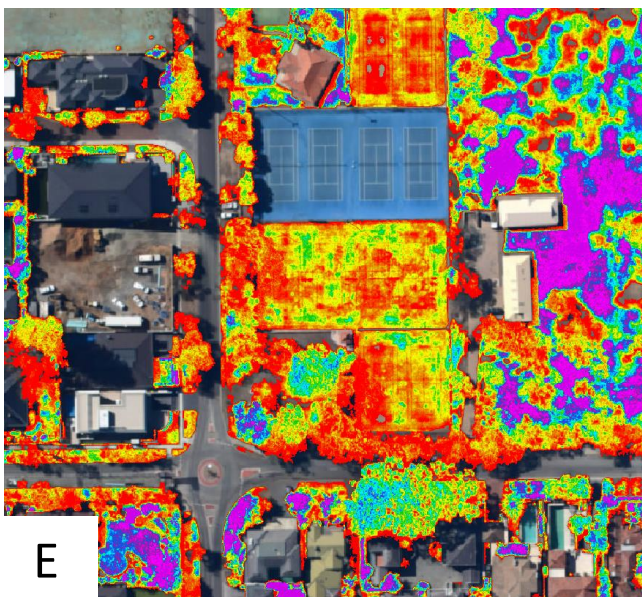
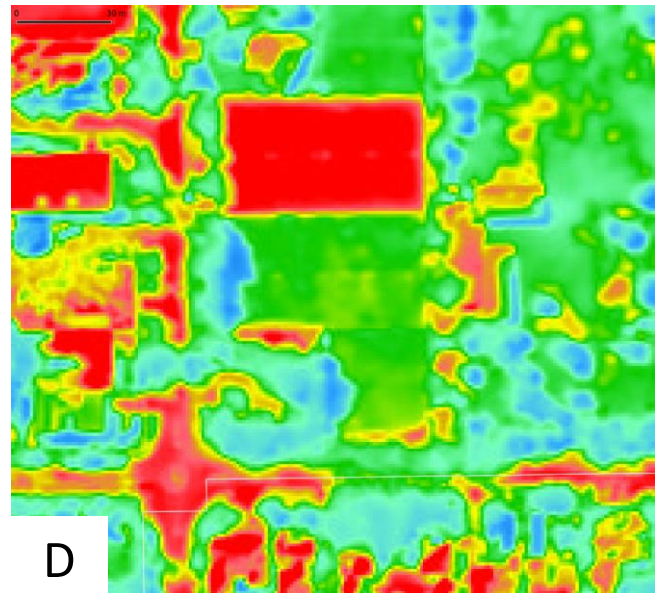
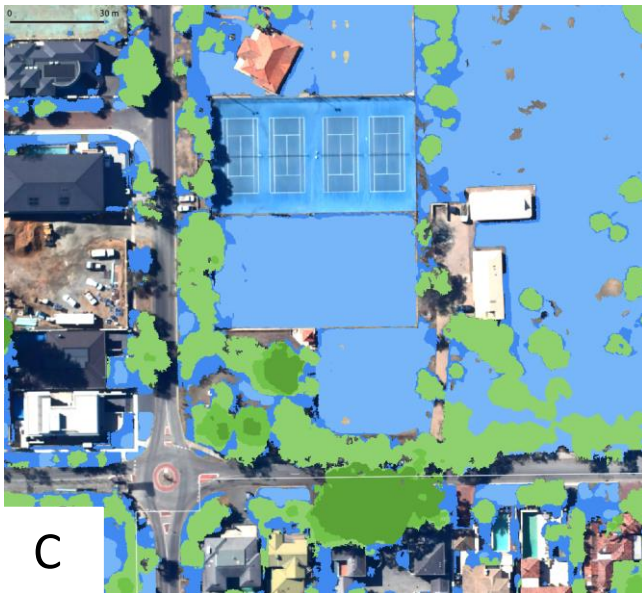
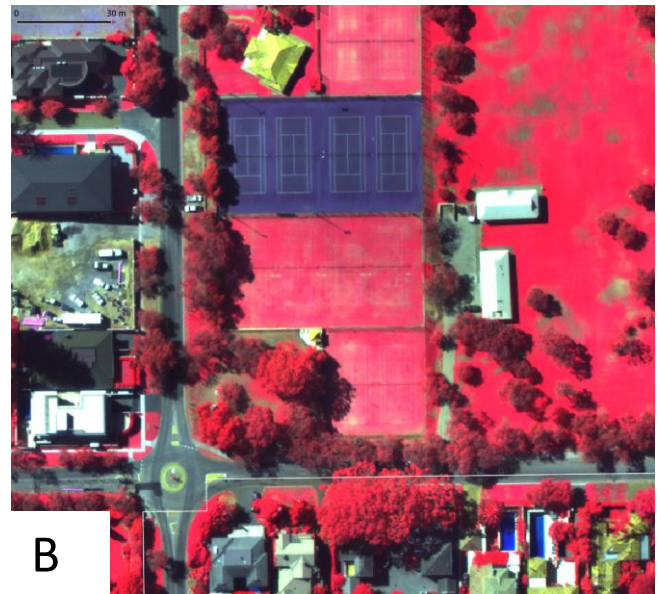


Figure 6: Close-up image of each of the datasets generated for WESROC: A) High-resolution RGB imagery; B) FCC showing vegetation in red; C) Height-stratified vegetation cover, with each stratum displayed as a different colour; D) land surface temperature, ranging from low (20°C; blue) to high (40°C;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

3.2.1 Town of Cottesloe

3.2.1.1 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 7 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 7 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.

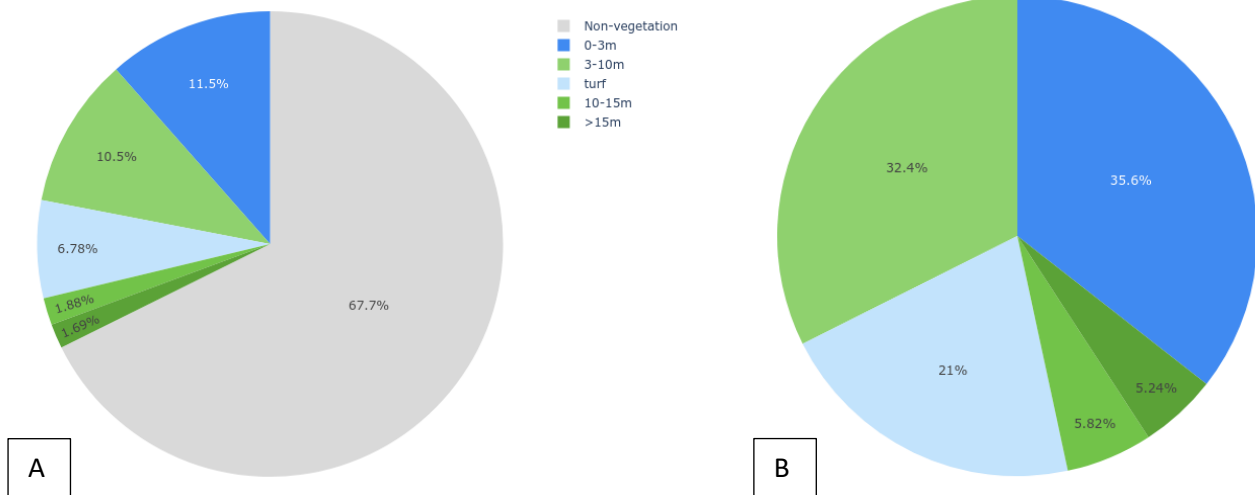


Figure 7: Land cover by strata (%) (A) and vegetation cover by strata (%) (B) of the Town of Cottesloe.

3.2.1.2 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 8 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 9.

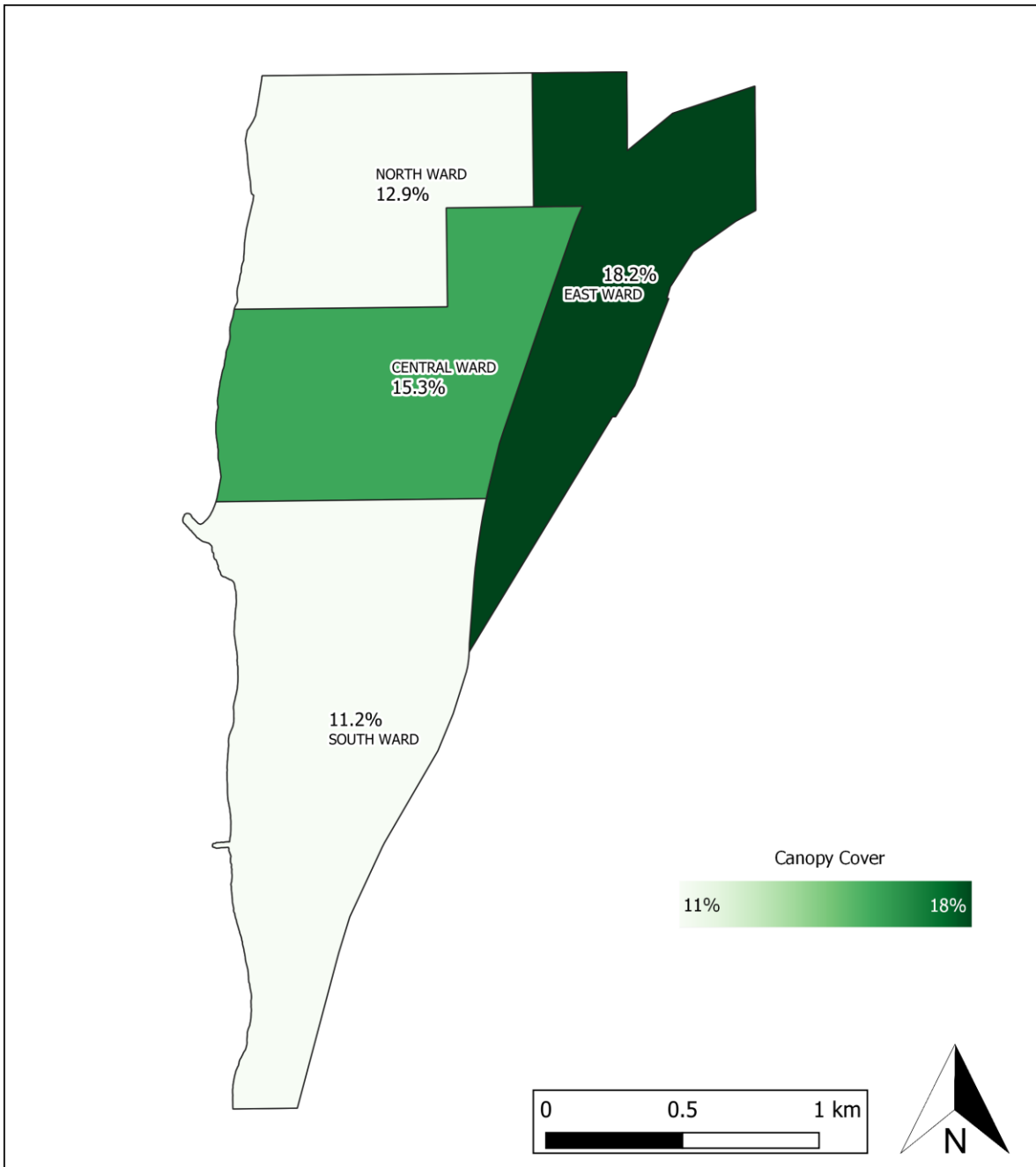


Figure 8: Thematic map showing canopy cover as a percentage of ward area. The darker green indicates higher relative canopy cover percentage.

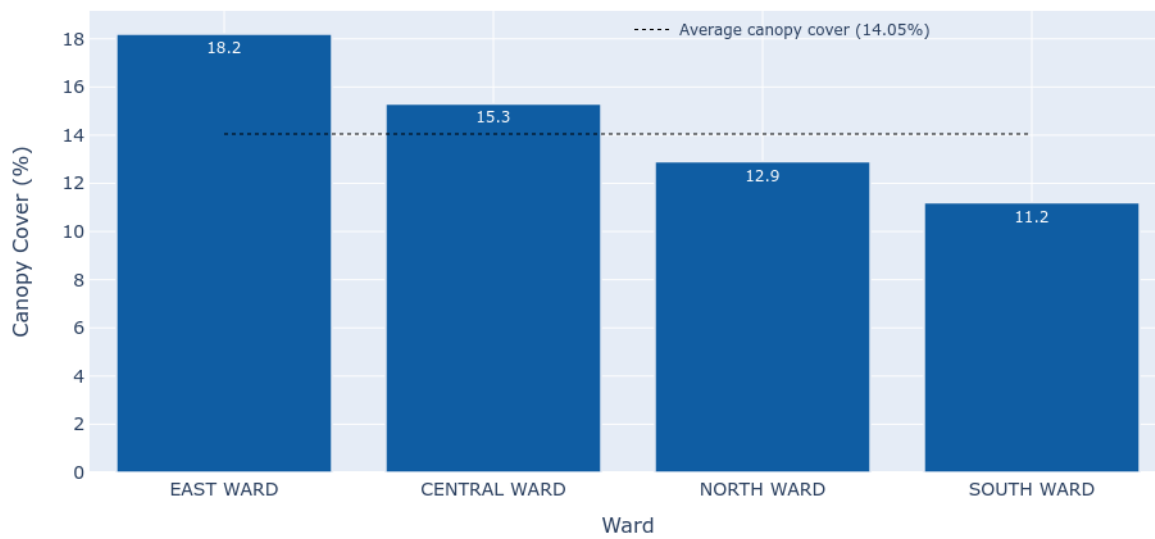


Figure 9: Canopy cover of each ward in the Town of Cottesloe by percentage of total ward area.

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 Town of Cambridge 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 10 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 10: 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

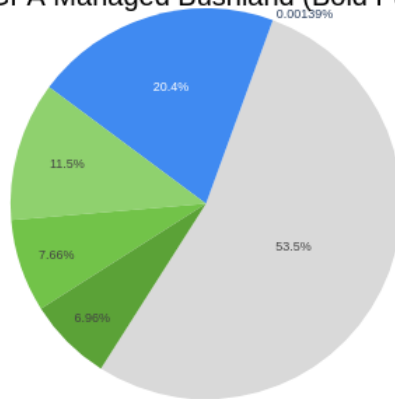
This study provides an accurate assessment of vegetation cover in the Town of Cottesloe in March 2020.

The main findings of this report are:

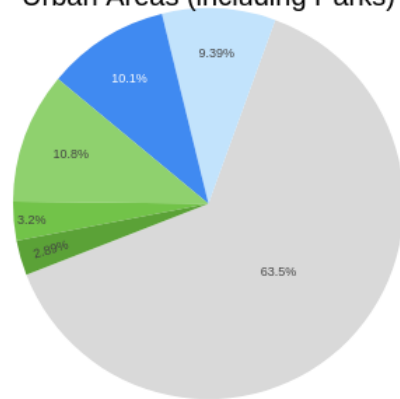
- The Town of Cottesloe had a total of 127 ha of vegetation across all strata, covering 32.3% of the Town's total area. Canopy made up 14% of the Town's total area.
- Of the Town of Cottesloe, the East Ward had the highest canopy cover (18.2%) while the South Ward had the lowest (11.2%).

Based on the findings of this analysis, we recommend Airborne multispectral vegetation surveys over the Town of Cottesloe 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.

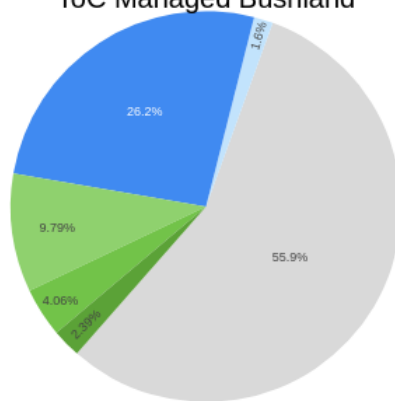
BGPA Managed Bushland (Bold Park)



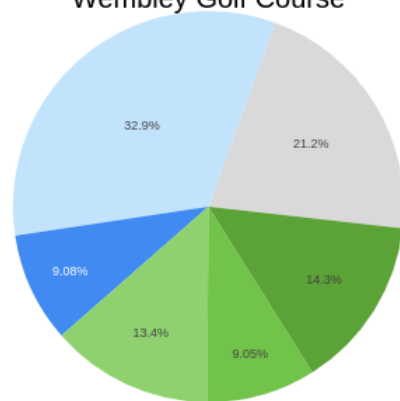
Urban Areas (including Parks)



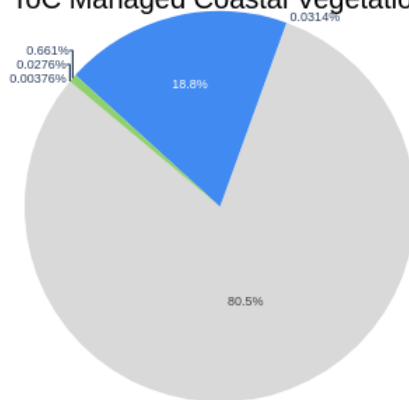
ToC Managed Bushland



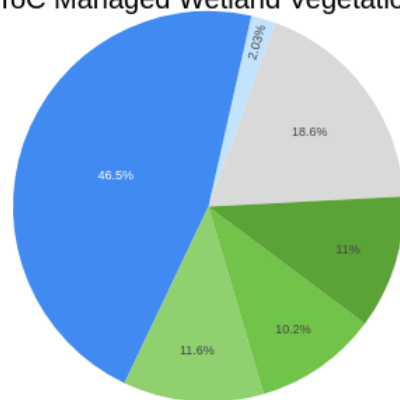
Wembley Golf Course



ToC Managed Coastal Vegetation

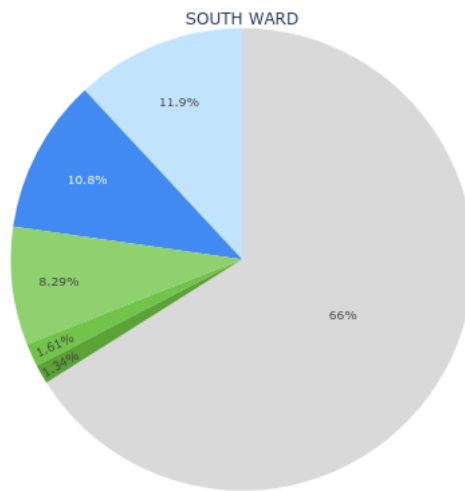
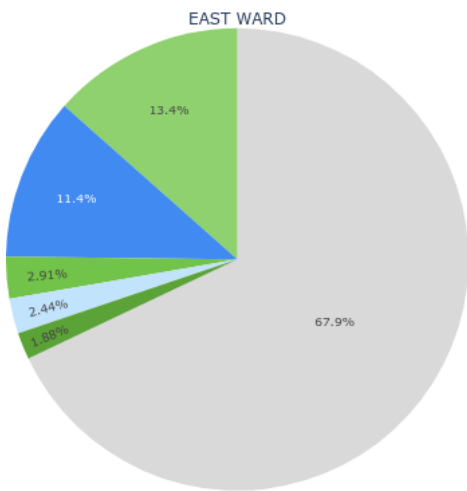
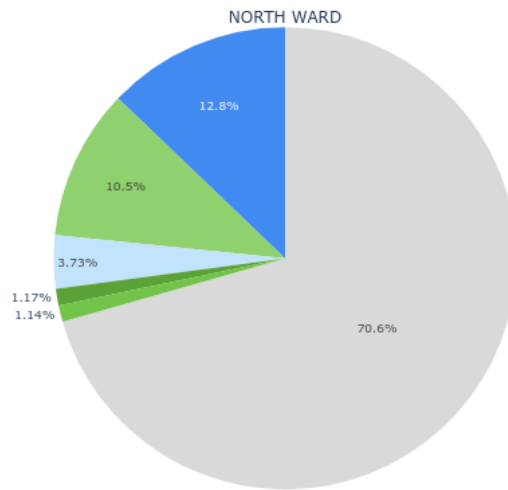
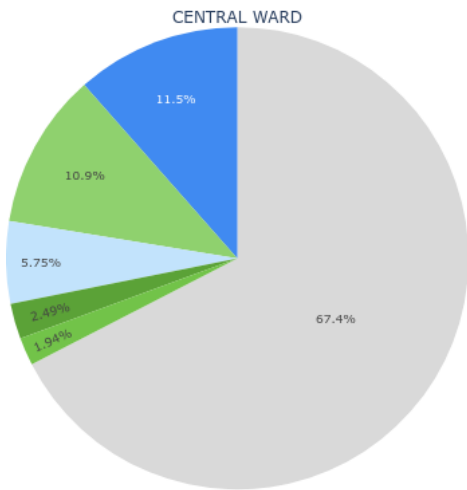


ToC Managed Wetland Vegetation



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

Appendix A - Vegetation Cover Proportions – Town of Cottesloe



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

Appendix F – Statistics

Town of Cottesloe

LGA	Area (ha)	Non-vegetation (ha)	Turf (Ha)	0-3m (Ha)	3-10m (Ha)	10-15m (Ha)	>15m (Ha)	Canopy (Ha)	Canopy (%)
COTTESLOE	392.91	265.89	26.64	45.17	41.15	7.39	6.66	55.20	14.0

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