Department of Planning, Housing and Infrastructure

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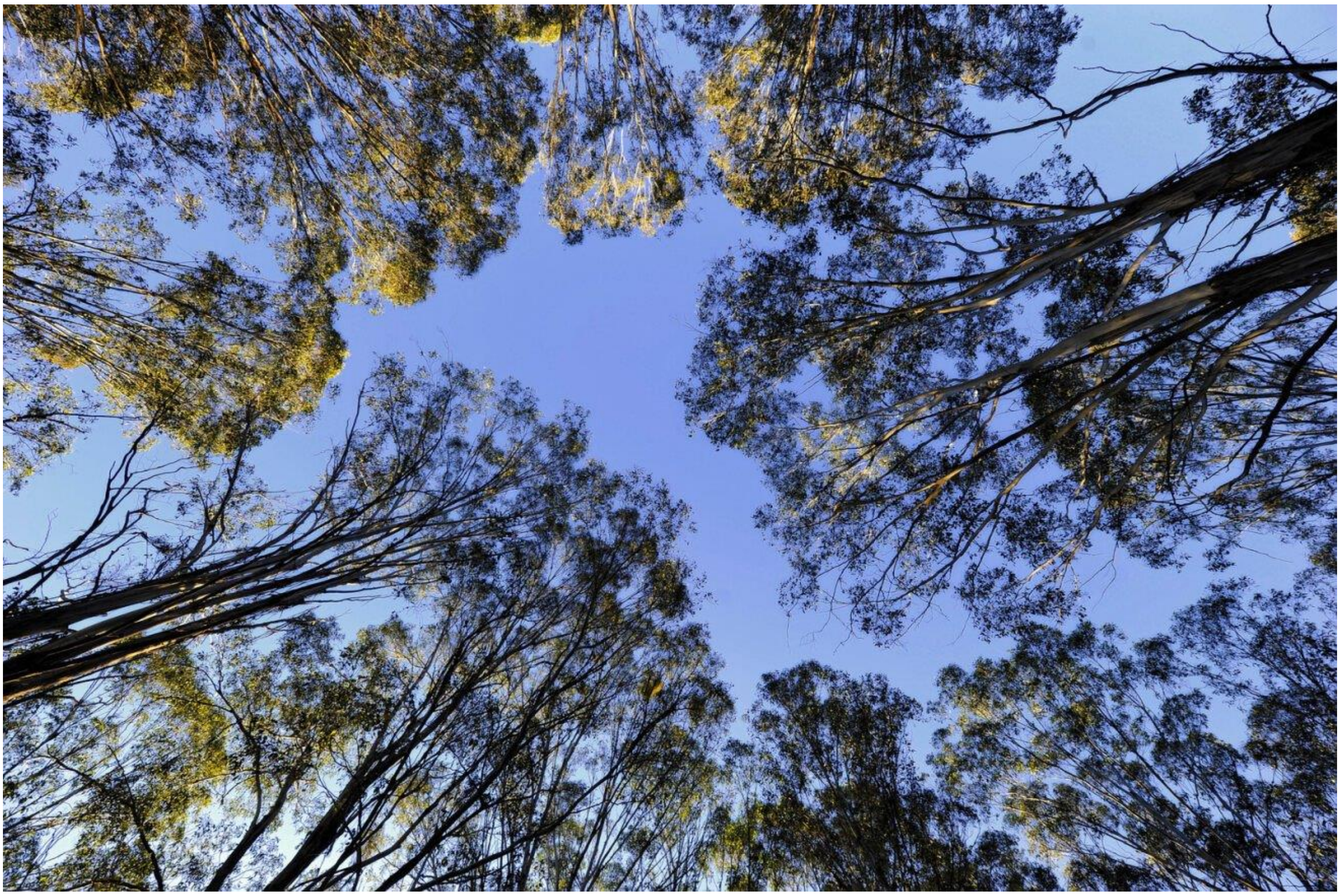
2022 Greater Sydney Region Tree Canopy Cover Dataset

Methodology Report

March 2024



Acknowledgement of Country

The Department of Planning, Housing and Infrastructure acknowledges that it stands on Aboriginal land. We acknowledge the Traditional Custodians of the land, and we show our respect for Elders past, present and emerging through thoughtful and collaborative approaches to our work, seeking to demonstrate our ongoing commitment to providing places in which Aboriginal people are included socially, culturally and economically.

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Contents

1 Introduction

This document outlines the method used to develop the 2022 Greater Sydney Region Tree Canopy dataset. The assessment of tree canopy is a key component of the NSW Greening our City Program (the Program) which aims to increase green cover across Greater Sydney and lift urban canopy coverage to 40% by 2036.

The dataset covers the metropolitan urban and metropolitan rural area of Greater Sydney, and includes information on:

- vegetation cover and height,
- vegetation condition,
- land surface temperature, and
- individual tree points.

A summarised version (to Modified Mesh Block) showing area and percentage of canopy for city blocks and infrastructure corridors was also developed for publication on the NSW Government SEED Portal (Greater Sydney Region Tree Canopy to Modified Mesh Block 2022).

2 Imagery Acquisition

The 2022 canopy dataset is based on remotely sensed imagery captured by ArborCarbon Pty Ltd (ArborCarbon) over the Greater Sydney Region.

The underlying aerial imagery for the 2022 canopy dataset was captured by ArborCarbon's unique and proprietary 11-band airborne multispectral camera system (ArborCamTM) optimised for the accurate measure of vegetation cover, condition, and land surface temperature.

The geographic extent of the acquisition covered the metropolitan urban and metropolitan rural areas of Greater Sydney (approximately 484,585.2ha) as shown in Figure 1.

High-resolution airborne imagery was acquired at altitudes between 16,000 and 18,000 feet above ground level over the acquisition area between 03 October 2022 and 20 February 2023. ArborCam imagery was acquired with a ground sample distance (GSD) ranging from 16 cm/pixel to 48 cm/pixel dependent on the spectral band. The thermal imagery was acquired with a GSD of 200 cm/pixel.

Preferable acquisition conditions were cloud and haze free, however, due to persistent poor weather conditions encountered during the acquisition period, some cloud was allowed.

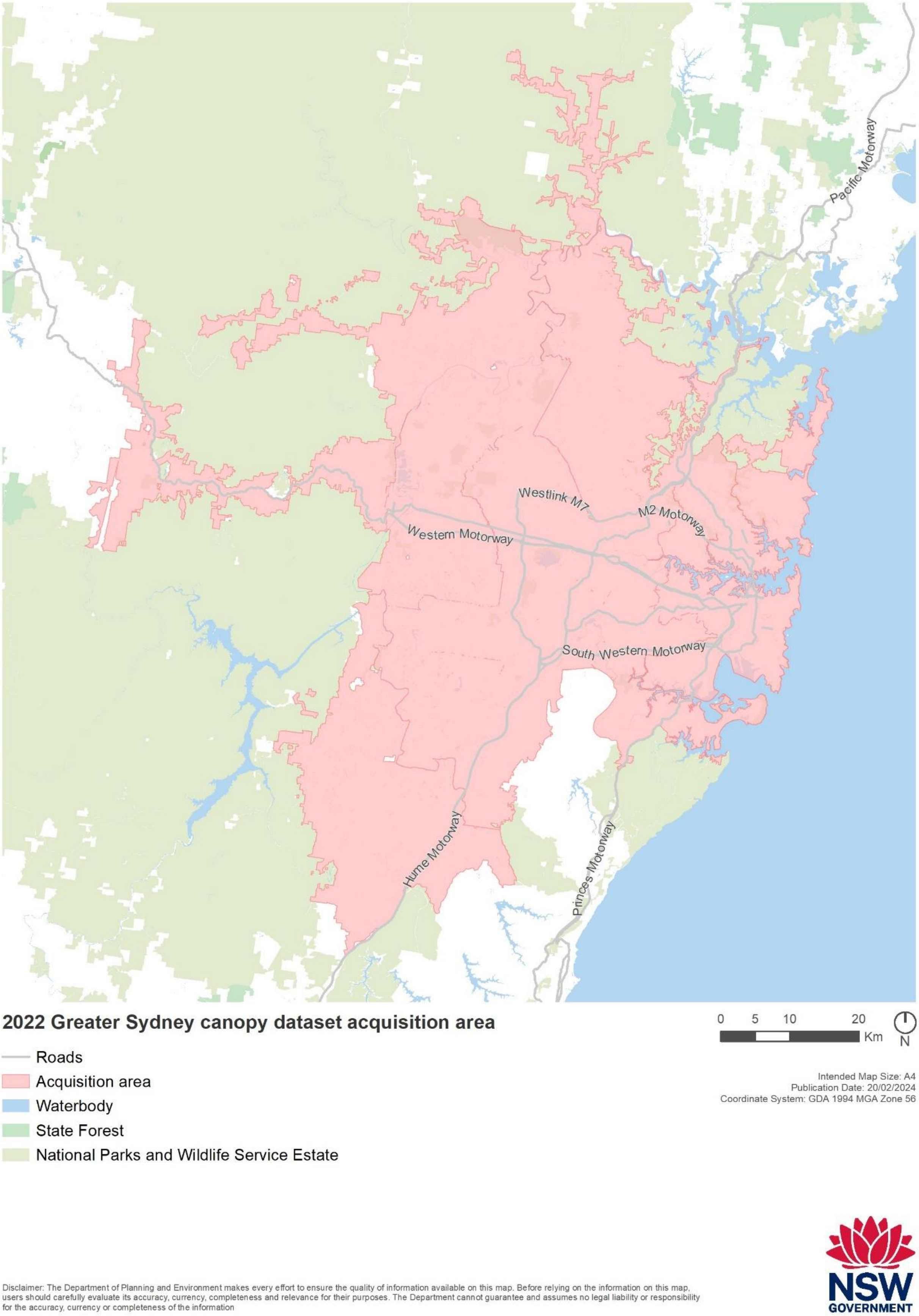

Figure 1 – 2022 Greater Sydney Canopy Data Acquisition Area

3 Data Processing

The acquired data was processed to produce high-resolution RGB imagery, False Colour Composite (FCC) imagery, a land cover classification dataset, vegetation condition index (VCI), land surface temperature (LST, °C) and tree inventory. Examples of imagery derived from each of these datasets and the different layers of information they provide are shown in figures 2 to 6.

The ArborCam imagery was geometrically corrected and orthorectified using airborne imagery available from the NSW Government Department of Customer Service Spatial Information Exchange (SIX Maps) (from 2018), and NSW Government 1m LiDAR derived Digital Terrain Model (data.nsw.gov.au) (from 2010 to 2020). The georeferencing process was based on invariant features, and therefore any features identified as having changed over time were not used.

A Digital Surface Model was generated from the acquired imagery for the full extent of the region, enabling the stratification of vegetation into five pre-determined height categories as follows: 0-3m, 3-10m, 10-15m, and >15m. For the purposes of this report, all vegetation >3m above the ground was classified as canopy. Vegetation that was not photosynthesizing at the time of acquisition, such as dead wood in tree crowns and dead or dry grass, was not classified as vegetation.

Due to the size of the dataset, the data was divided by Local Government Area (LGA) for ease-of-use.

High resolution imagery

Figure 2: High resolution 3-band RGB

False Colour Composite

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

Figure 3: False Colour Composite (FCC) showing vegetation in red, derived from the 7-band multispectral imagery

Vegetation Cover and Height

The land cover classification dataset (Figure 4) is comprised of specific height strata colourised as follows: 0-3m blue, 3-10m light green, 10-15m green, and >15m dark green.

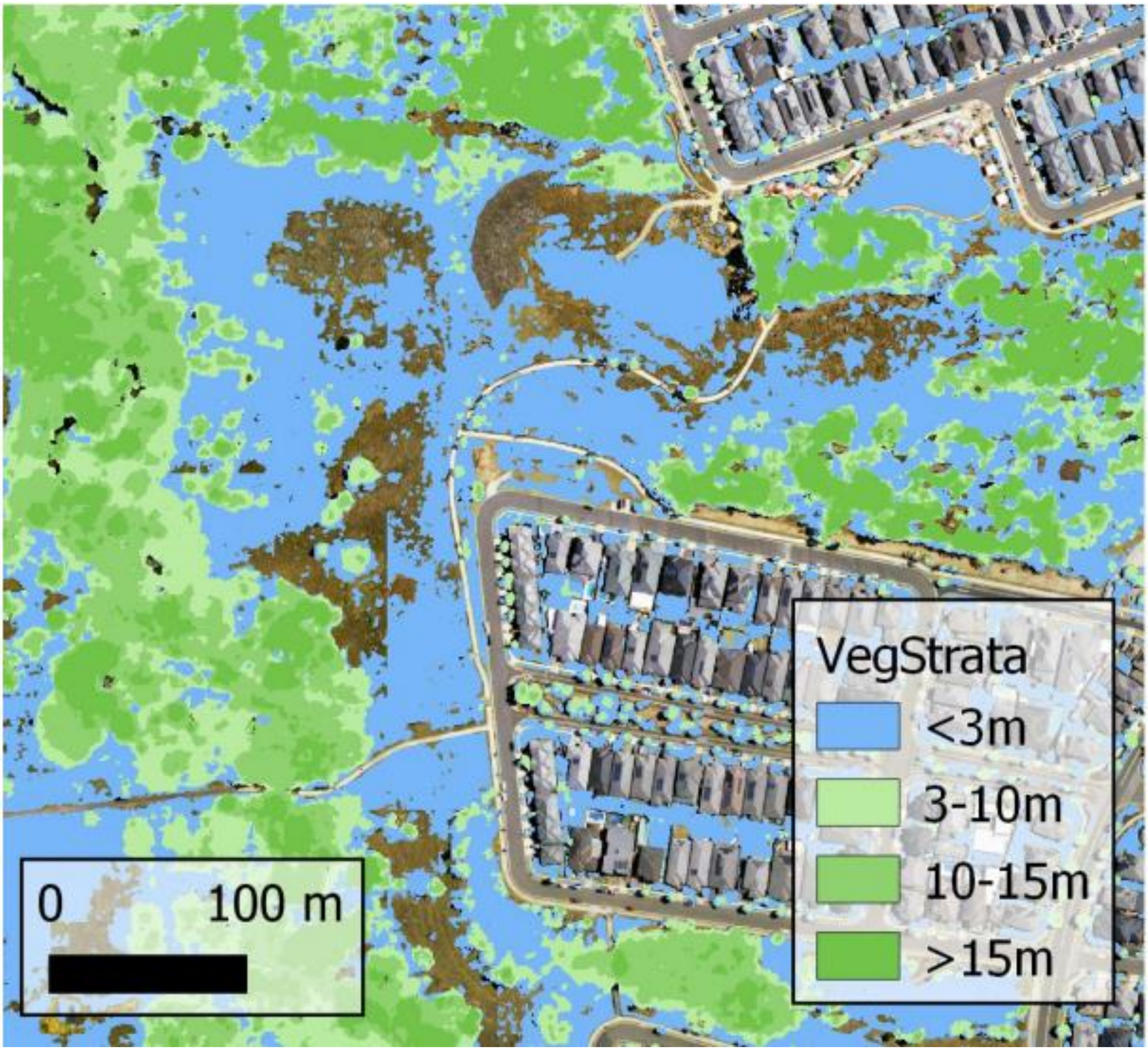

Figure 4: land cover classification dataset, with each stratum displayed as a different colour; blue (15m)

Vegetation Condition Index

VCI is a quantitative measure of vegetation condition relating to the density, colour, internal cellular structure, and photosynthetic activity of foliage. It is derived from a 2-band subset of the multispectral imagery (NIR and red).

Stress impacting plant function (e.g., photosynthesis) can be detected using VCI. In general, a higher VCI value may indicate higher vegetation condition, while a lower VCI value indicates lower vegetation condition. VCI also varies independently of vegetation condition, with factors such as tree species, maturity, and plant phenology. For this reason, comparisons of VCI values are most reliable when made between vegetation of the same species. For example, comparing the condition of Jacaranda trees between parks is a more robust approach than comparing the overall condition of all trees between parks, which may have different species profiles.

The true value of acquiring VCI data over an area with a diverse tree population such as the Greater Sydney Region, 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 identify areas of vegetation with low and high condition. Figure 5 illustrates the different VCI levels that can be observed among vegetation throughout the region.

The VCI imagery was colour-scaled separately for each Local Government Area (LGA) to provide the greatest ‘contrast’, allowing more subtle variations to be visualised compared to a ‘one size fits all’ scaling. As the imagery for some LGAs was captured months apart, a single scale across the entire acquisition area would have resulted in some LGAs being visually compressed. Due to this approach, the imagery for each LGA has an independent VCI scale.

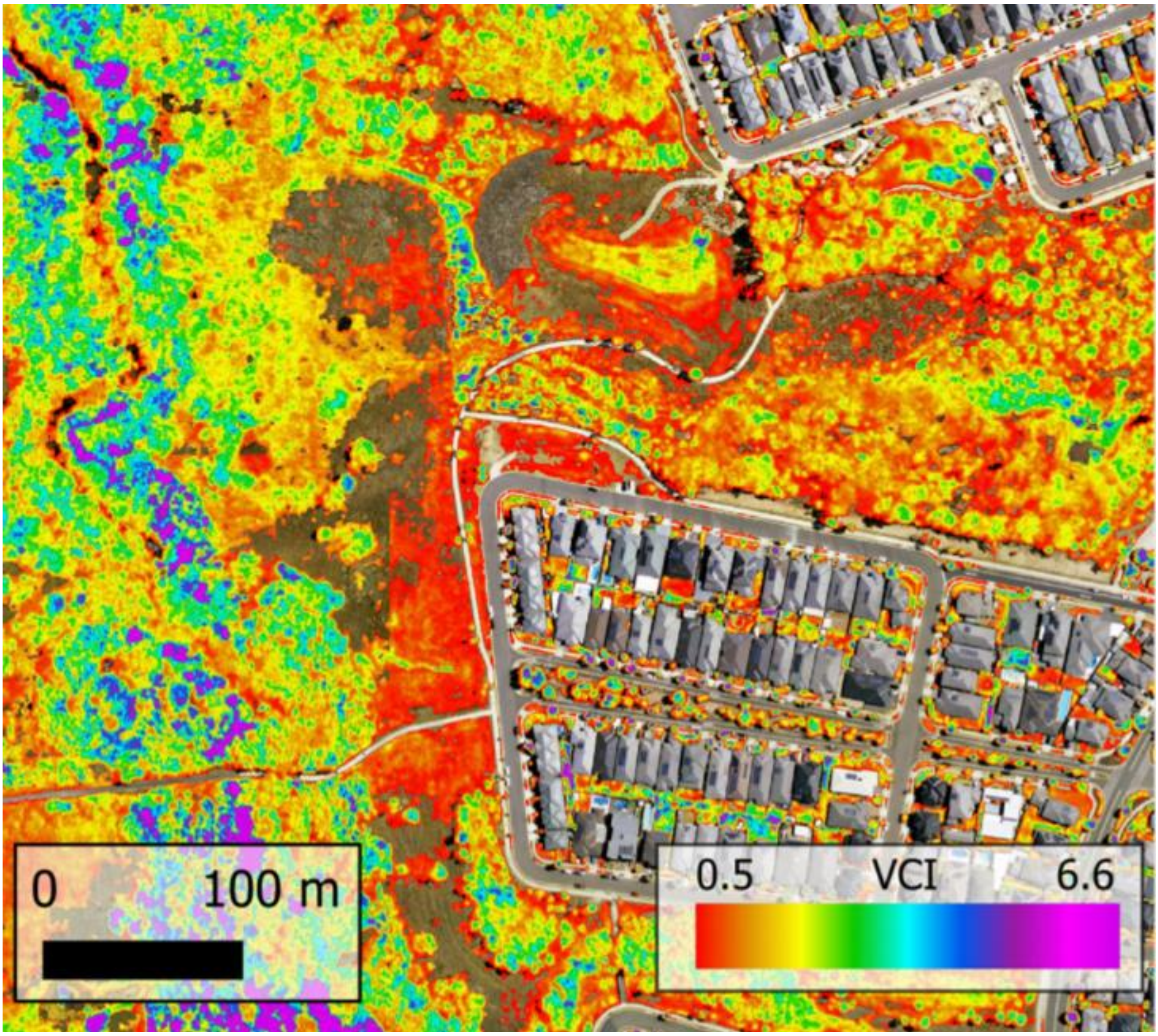

Figure 5: Vegetation Condition Index (VCI) used for the calculation of vegetation condition statistics and colour-scaled from low reflectance (red; 0.5) through to high reflectance (magenta; 6.6)

Land Surface Temperature

Land surface temperature (LST) is the radiative temperature of the land derived from solar radiation. LST measures the emission of thermal radiance from the land surface where the incoming solar energy interacts with and heats the ground, or the surface of the canopy in vegetated areas. Land surface temperature is a measure of how hot the land is and is different to air temperature because land heats and cools more quickly. It is measured in degrees Celsius. The LST imagery was colour-scaled separately for each Local Government Area (LGA). Therefore, the imagery for each LGA has an independent LST scale. An example of the LST layer is shown in Figure 6.

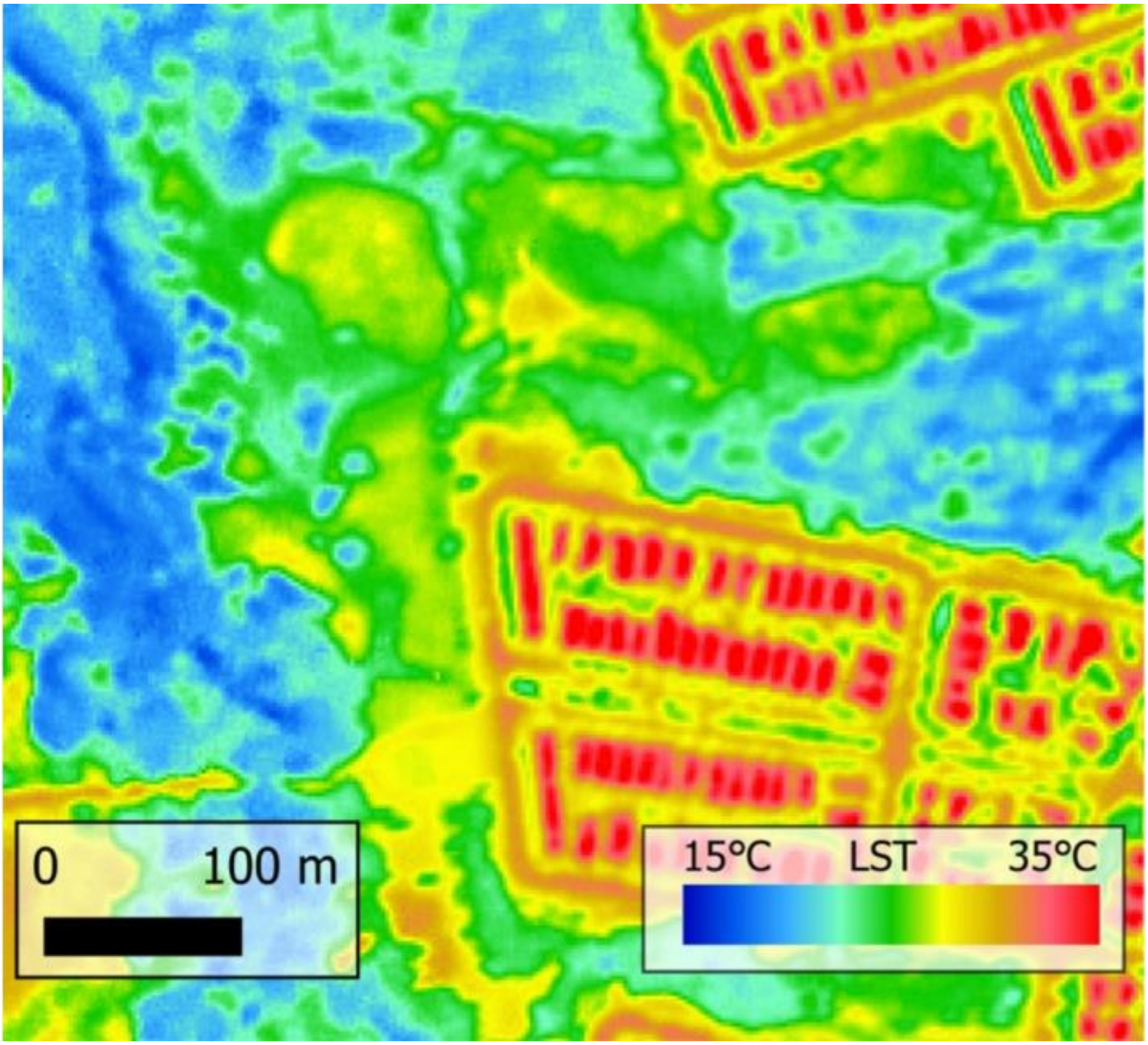

Figure 6: Land Surface Temperature showing low (blue; 15°C) and high temperatures (red, 35 °C).

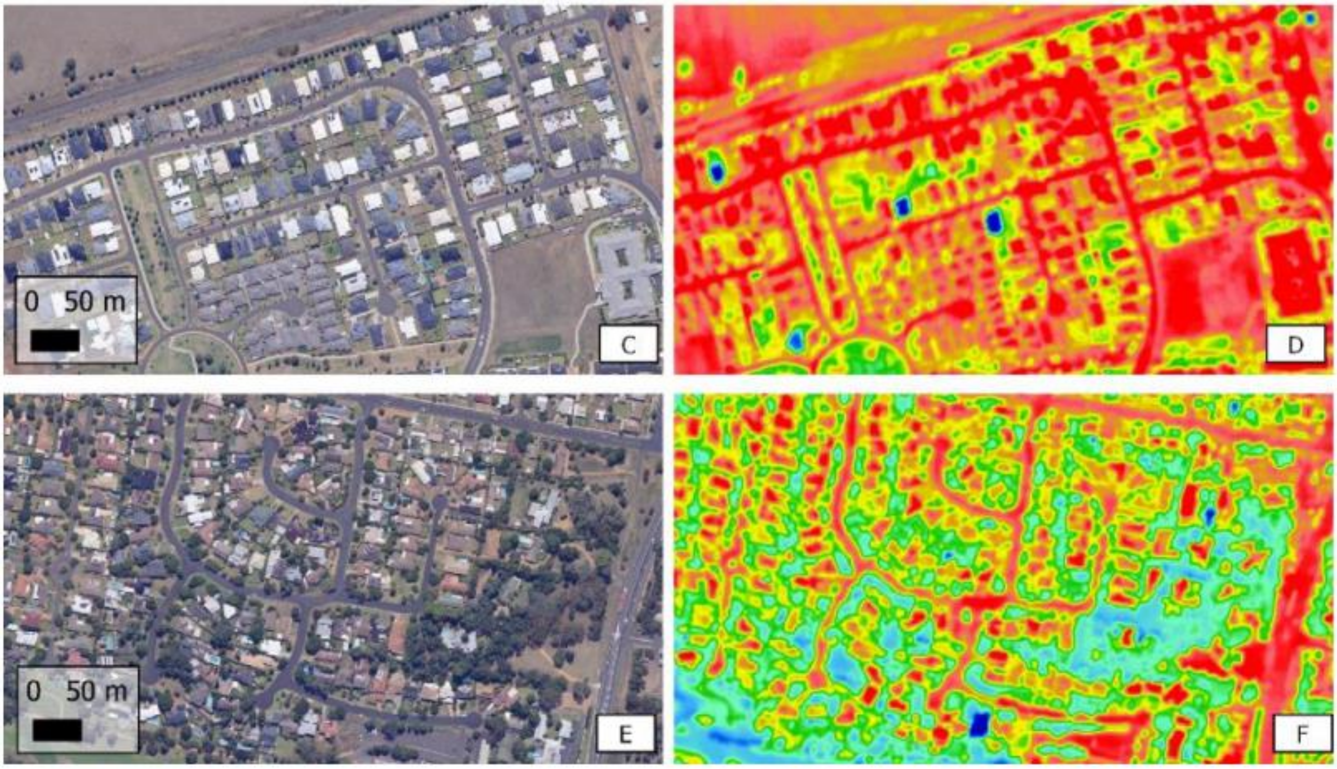

Figure 7: Examples of thermal hotspots throughout Greater Sydney region, and the impact of vegetation on LST.

Different materials absorb and retain heat at different rates, resulting in different surface temperatures. In general, impervious surfaces, such as buildings, roads, carparks, synthetic turf, dead grass and bare earth have higher land surface temperatures. Built-up areas with more impervious surfaces and less vegetation tend to have higher LST (Figure 7 C and D, E and F).

In the imagery (Figure 7), some rooftops appear very cool in comparison to other surfaces. This is likely due to differences in emissivity of different roof materials. Certain construction materials used in rooftops can have low emissivity values and therefore their surface temperature appears very low. A standard emissivity correction of 0.95 was applied to the whole scene, as the majority of surfaces throughout a city are likely to have an emissivity value of around 0.95 and the target of this project was vegetation (which has an emissivity of 0.95). However, some buildings may have an emissivity of as low as 0.6, and therefore were unlikely to be entirely corrected, and as such would display a surface temperature lower than their actual temperature. It is possible to apply different emissivity corrections to various materials if multispectral imagery is used for prior classification of these materials within the imagery. This was beyond the scope of the current project.

Tree Inventory

A tree inventory dataset was derived from the 2022 raster imagery. The inventory data was delivered in vector format and shows estimated crown centre point, estimated tree height, and estimated crown diameter. An example of the tree inventory layer is shown in Figure 8.

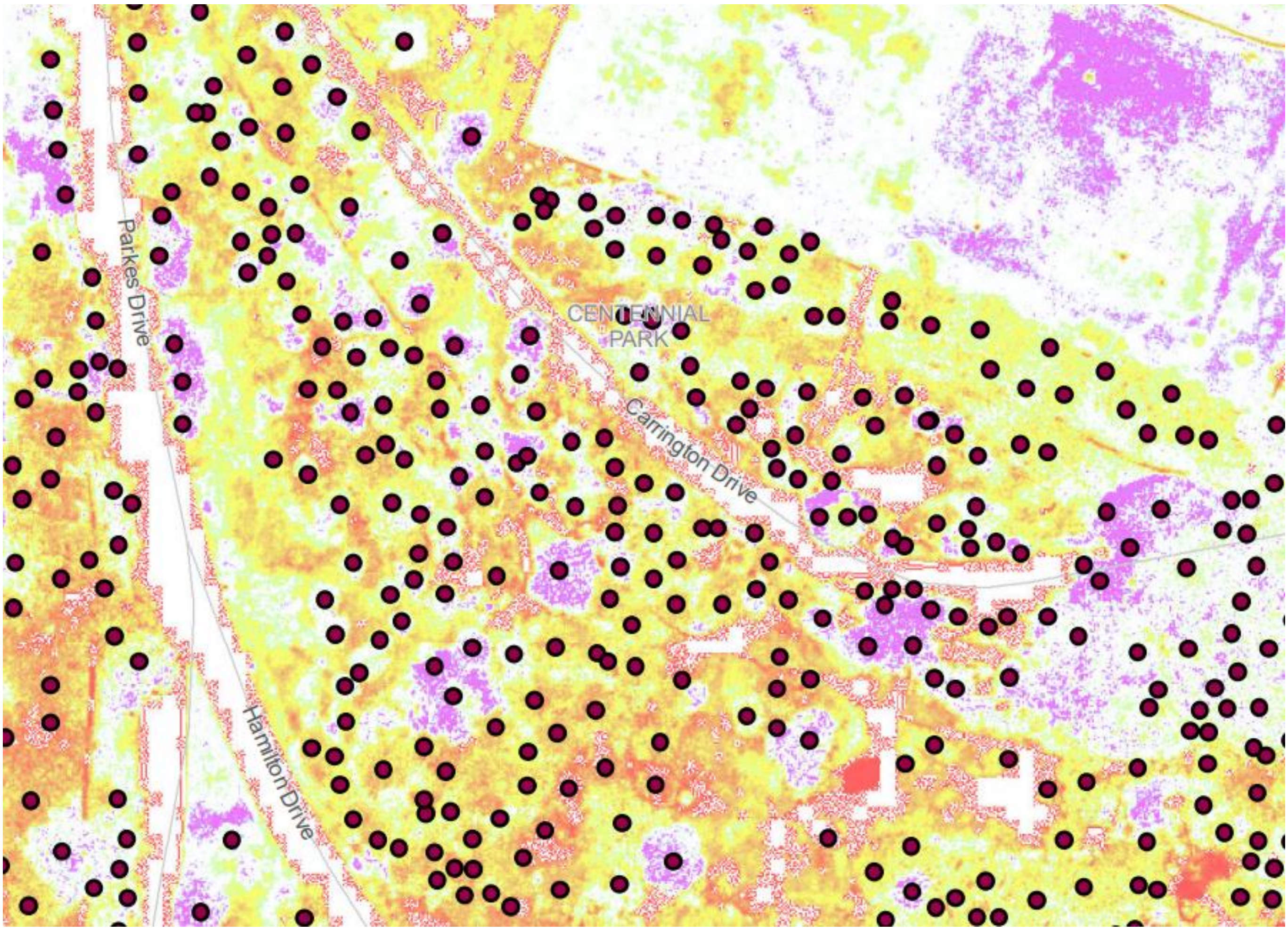

Figure 8: tree inventory data points overlayed on vegetation condition data.

4 Dataset Limitations

Cloud Cover

Adverse weather conditions, especially cloud cover had an impact on the canopy capture. To mitigate the impact of cloud artifacts in the imagery, ArborCarbon leveraged a high frame rate of acquisition and applied substantial overlapping of ArborCam imagery, which facilitated effective patching of imagery across the acquisition area.

In most instances, these measures successfully mitigated the impact on land cover classification and the vegetation height model, except for the Blue Mountains and Wollondilly Local Government Areas (LGAs). Despite multiple acquisition attempts, it was not possible to acquire sufficient cloud-free data in these LGAs, leading to certain localised impacts on the accuracy of the vegetation height model. Approximately 2% of Blue Mountains and Wollondilly have been estimated to be affected by cloud cover, which were patched using the method in the following section.

Gaps in Acquisition

Additional gaps in the acquired data occurred across approximately 90 square kilometres of the acquisition boundary. The data for these areas was not captured due to adverse weather which limited the time available to undertake the entire acquisition. Due to this, small, isolated areas positioned away from the main acquisition area were excluded from the aerial acquisition. This decision was informed by engagement with affected councils.

The height stratified vegetation cover data was patched using Six Maps airborne imagery in these areas (example of patching shown in Figure 10), as this was the most fit-for-purpose available data at the time. An AI model was developed to replicate the ArborCarbon vegetation classification outputs, and these were patched into the area. The most recent data available (from 2018) was used to patch each gap. The approximate location of areas patched is shown (hatched) in Figure 9.

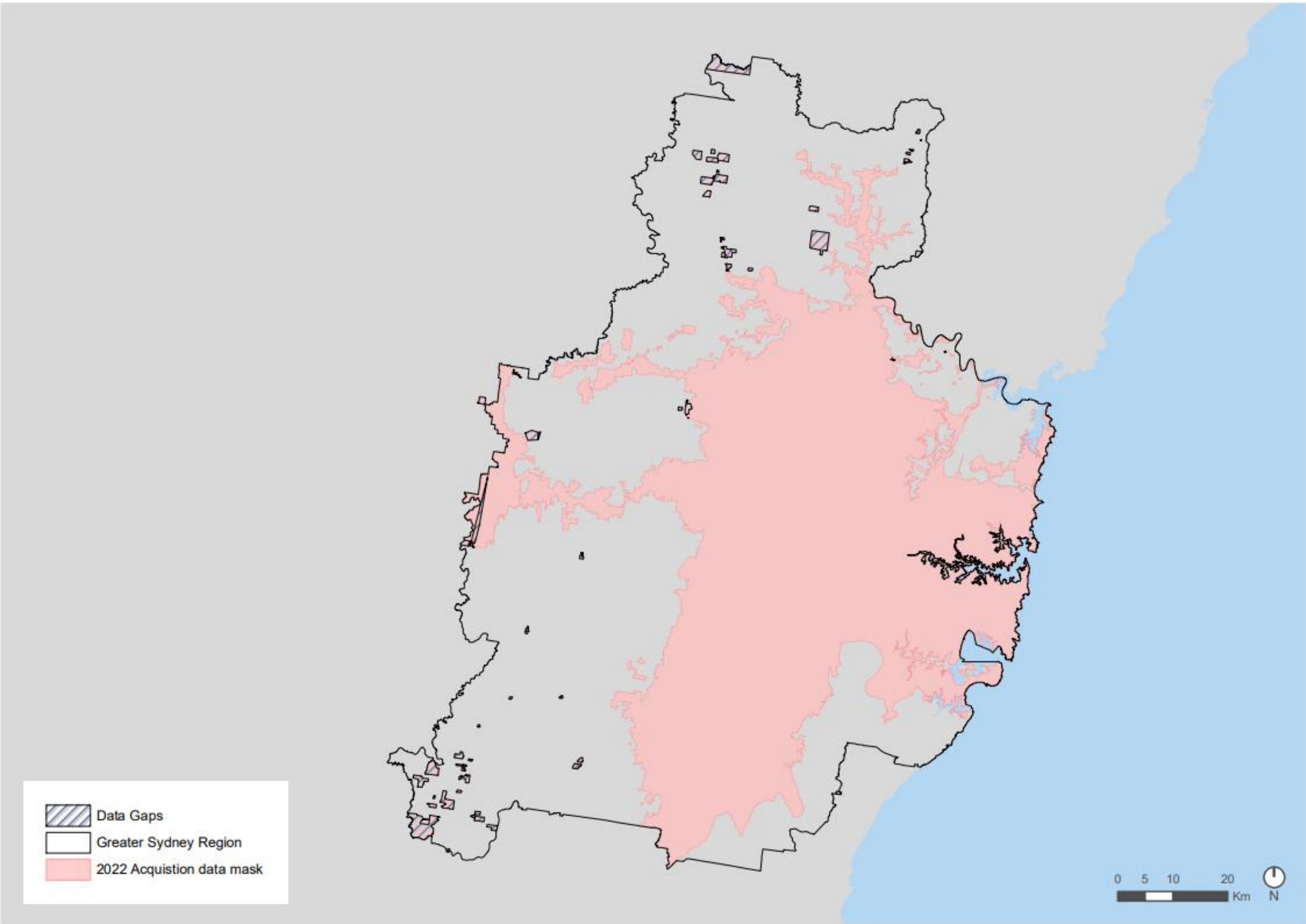

Figure 9: approximate location (hatched) of areas not captured during acquisition.

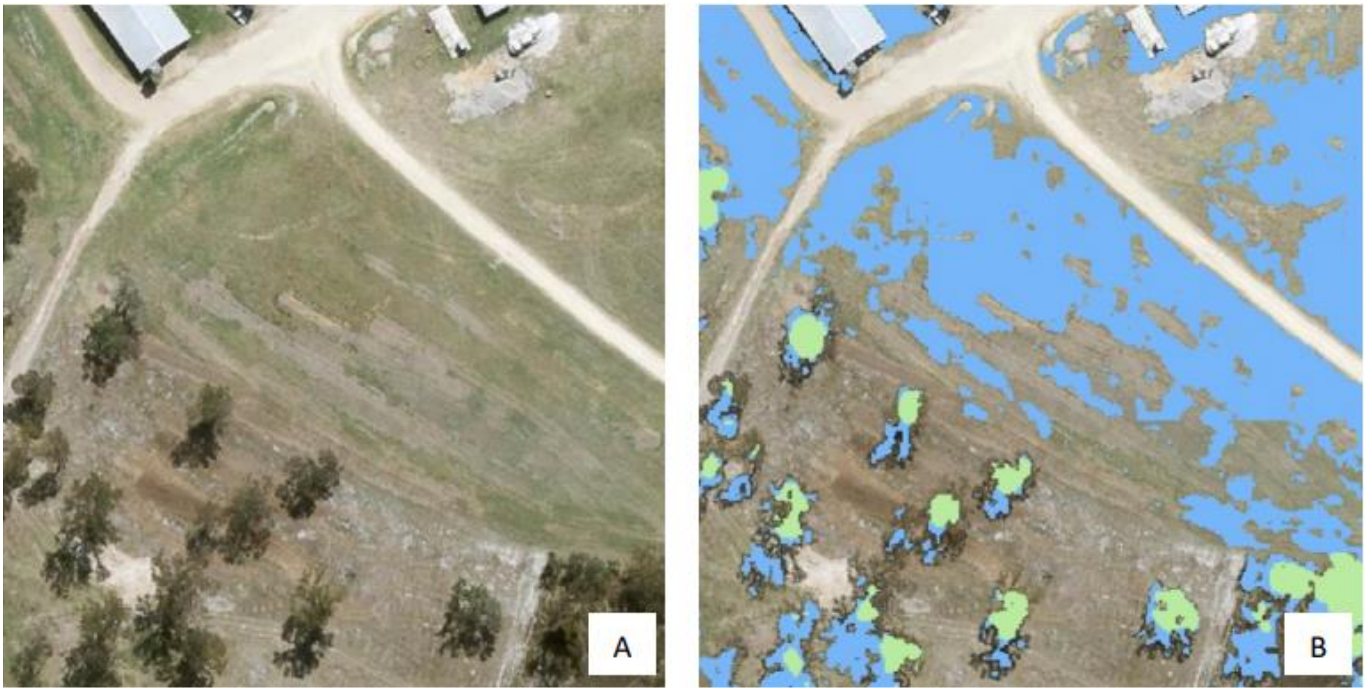

Figure 10: Example of Six Maps airborne imagery used in the vegetation classification AI model in areas where data was not acquired (A) and the resulting outputs of the model (B).

Turf

The 0-3m height stratum in the land classification dataset encompasses vegetation with a height of less than 3m, which includes shrubs, groundcover, and turf.

Some turf areas visible in the high-resolution RGB imagery were not captured in the land classification. This can be attributed to the data acquisition period spanning a 4 – 5-month period between early October 2022 and late February 2023 across the capture region. Since turf is known to exhibit transient characteristics, its greenness and overall vitality can vary significantly due to fluctuations in environmental conditions during this timeframe. Additionally, in certain regions, the multispectral imagery used for vegetation classification was acquired on a different date than the RGB imagery. As a result, changes in turf greenness during the acquisition period may lead to instances where areas that appear as turf in the RGB imagery are not identified as turf in the multispectral imagery. Consequently, the detection of turf within the dataset may exhibit variations in frequency across different areas. Examples of turf limitations are shown in Figure 11.

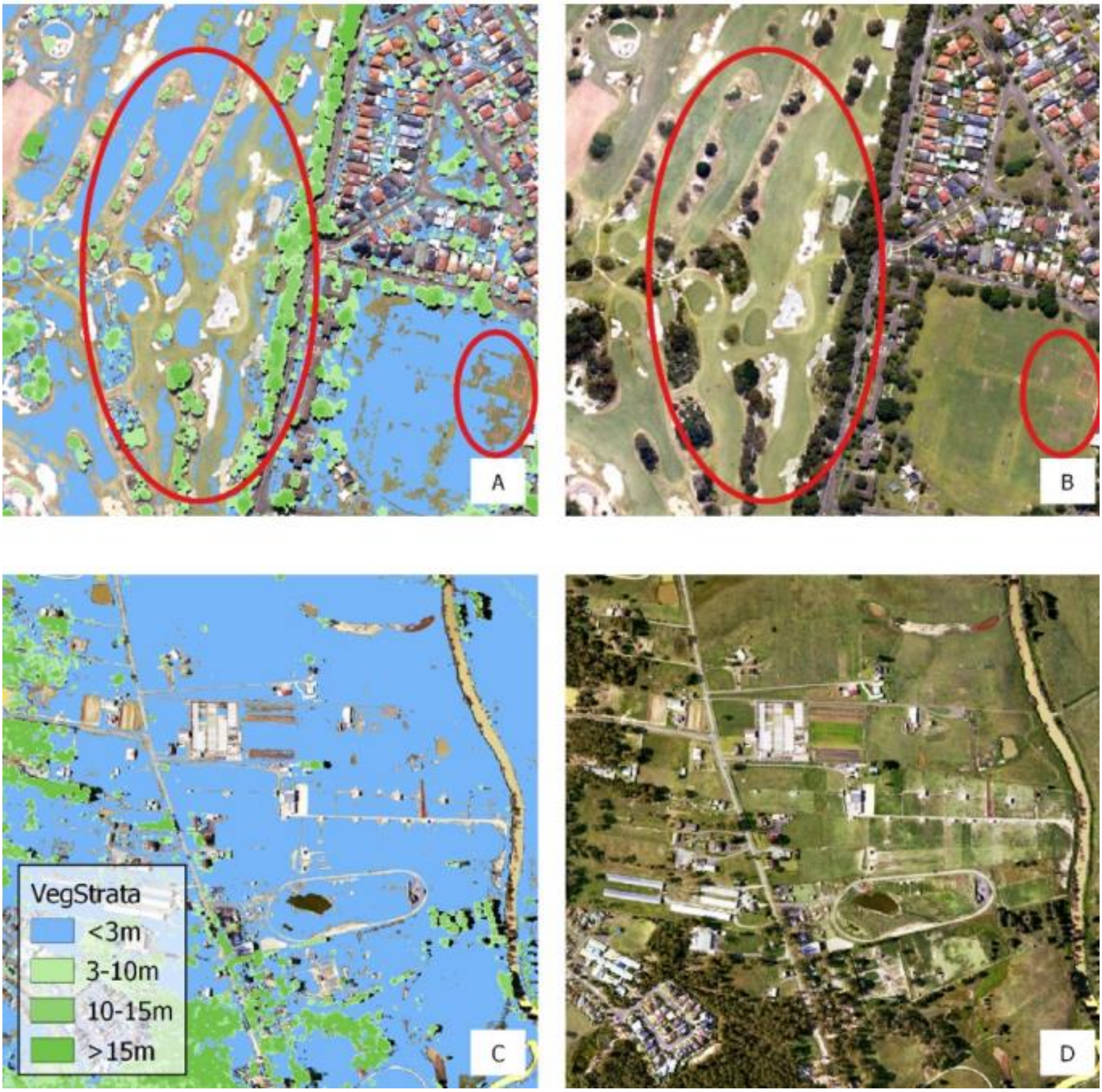

Figure 11: Examples of inclusion and exclusion of turf in the 0-3m land cover classification (A) turf not captured in the vegetation <3m in height, while appearing as vegetation in the RGB imagery (B). (C) shows the majority of turf captured in the land cover classification that exhibits as turf in (D).

Jacaranda Mask

Part of the acquisition occurred during the jacaranda tree (jacaranda mimosifolia) flowering season. A sizeable number of jacarandas occur in several LGAs throughout the acquisition area, which impacts canopy cover figures. Flowering jacarandas are generally missed from the vegetation classification using standard image analysis techniques. To mitigate this, an artificial intelligence (AI) model was trained to classify flowering jacarandas, resulting in the delineation of tree crowns as polygons. These polygons were added to the existing vegetation classification and classified according to height. An example of the jacaranda mask is shown in Figure 12.

Figure 12: Flowering jacaranda trees (A) and the outputs of the custom AI model for the detection of flowering jacaranda trees (B).

VCI and Land Surface Temperature Datasets

The VCI and LST datasets are outputs of the ArborCam multispectral and thermal imagery. Since the acquisition took place over a period of 4-5 months, both datasets were acquired over a wide range of acquisition conditions, including different air temperatures, cloud cover and times of day. These conditions impact consistency of the VCI and LST datasets across the entire acquisition area.

In order to acquire canopy cover data prior to autumn defoliation, ArborCarbon acquired data outside of optimal sun angles, acquiring data with clouds and cloud shadows present, and acquiring imagery with fewer independent views per pixel (overlap). These factors, in conjunction with the acquisition spanning from mid spring to late summer, may have a larger impact on VCI and LST than variability due to physical differences in condition or temperature.

Given these constraints, the VCI and LST datasets are best compared in localised areas rather than across the whole scene. Additionally, the commencement of acquisition in early spring meant that many jacaranda trees were still in bloom. Flowering jacaranda trees have markedly different reflectance properties compared to most other types of vegetation and are typically missed in vegetation classification datasets.

While this limitation was overcome with the development of an AI model specific to flowering jacaranda plants (Figure 12), it was not possible to adjust their VCI reflectance. As such, many flowering jacarandas appear to have very low VCI reflectance, particularly toward the east of the Greater Sydney Region where acquisition commenced. The jacaranda flowering season finished mid-way through the acquisition, and jacaranda trees had more typical VCI reflectance from this point onward.

5 Data Analysis

5.1 Canopy cover by Modified Mesh Block

The 2022 Greater Sydney Region Tree Canopy dataset was summarised to Modified Mesh Block (MMB) and published on the NSW Government SEED portal. The summarised dataset provides an area and percentage of stratified tree canopy and vegetation cover, for city blocks and infrastructure corridors in the Greater Sydney Region.

The 2022 canopy vegetation classification dataset was intersected with the 2019 MMB boundaries to create the Greater Sydney Region Tree Canopy to Modified Mesh Block 2022 dataset. More information on the underlying methodology for the 2019 MMB boundaries can be found here: A workflow for assessing tree canopy cover in the Greater Sydney Region (NSW Department of Planning, Industry and Environment 2019).

Geometries and attribute data from the 2019 MMB dataset was sourced from the NSW SEED portal and clipped to the acquisition extent of the 2022 Greater Sydney Region.

The dataset was updated with new attributes based on analysis of the 2022 Greater Sydney Region canopy dataset as follows:

- class (string): owner (public or private), classified using the MMB_CAT attribute value as follows:
    - Public: Road, Recreational, Environmental, Water, Railway, education, Hospital/Medical, Airport
    - Private: Residential, Commercial, Primary Production, Industrial
- area (ha) (float): total feature area, in hectares
- Non-Vegetation (float): area of non-vegetation, in hectares
- 0-3m (float): area of vegetation <3m tall, in hectares
- 3-10m (float): area of vegetation 3-10m tall, in hectares
- 10-15m (float): area of vegetation 10-15m tall, in hectares
- >15m (float): area of vegetation >15m tall, in hectares
- Canopy (float): area of canopy (all vegetation >3m tall), in hectares
- Non-Vegetation % (float): non-vegetation cover as a percentage of total feature area
- 0-3m % (float): vegetation cover <3m tall as a percentage of total feature area

- 3-10m % (float): vegetation cover 3-10m tall as a percentage of total feature area
- 10-15m % (float): vegetation cover 10-15m tall as a percentage of total feature area
- >15m % (float): vegetation cover >15m tall as a percentage of total feature area
- Canopy (float): canopy cover (all vegetation >3m tall) as a percentage of total feature area

All other attributes in the dataset were propagated without modification from the 2019 Modified Mesh Block dataset.

5.2 Canopy cover by LGA and suburb

The department published summary statistics for the 2022 canopy dataset on the SEED portal. Statistics show canopy cover area and percentage for LGA and suburbs in the metropolitan urban area (MUA).

An updated analysis was also undertaken on the 2019 Greater Sydney Region Vegetation dataset using the same statistical boundaries as 2022. The updated statistics were included in the 2022 canopy cover statistical spreadsheet on the SEED portal.

The LGA and suburb boundaries were sourced from 2019 GSR Footprint, Greater Sydney Region Tree Canopy to Modified Mesh Block 2019, NSW SEED. The LGA and suburb boundaries used for analysis (of 2022 and 2019) have been modified according to the metropolitan urban area, cadastre and 2022 program capture area. As a result, deviation from gazetted LGA and suburb boundaries are to be expected.

The statistics were published for the MUA to maintain consistent geographic reporting across all NSW Government tree canopy datasets.

A summary of statistics published has been provided in Table 1.

Canopy dataset year	Statistics published
2022	• LGA MUA area (ha) • LGA MUA canopy area (ha) • LGA MUA canopy percentage (%) • suburb MUA area (ha) • suburb MUA canopy area (ha) • suburb MUA canopy percentage (%)

2019	• LGA MUA area (ha) • LGA MUA canopy area (ha) • LGA MUA canopy percentage (%) • suburb MUA area (ha) • suburb MUA canopy area (ha) • suburb MUA canopy percentage (%) • LGA Total* area (ha) • LGA Total* canopy area (ha) • LGA Total* canopy percentage (%) • suburb Total* area (ha) • suburb Total* canopy area (ha) • suburb Total* canopy percentage (%)

Table 1: Summary of statistics published in the 2022 canopy cover statistical spreadsheet.

* The 2019 Total LGA and suburb boundaries are as defined by NSW Spatial Services and represent the complete LGA and suburb areas located in the Greater Sydney Region, clipped to the cadastred area. Statistics for the Total LGA and suburb areas for the 2019 dataset have been included for reference.

5.2.1 Temporal analysis

Best efforts were made to develop comparable statistics for the 2022 and 2019 canopy datasets using the raster base imagery. However, due to differences in data acquisition and processing methods, there may be some variation in the summary statistics.

Care should be taken when comparing canopy cover between datasets, especially in LGAs with a lower proportion of MUA, as some observed differences may be a result of variations in methodologies rather than actual change in canopy cover.

The proportion (%) of LGAs covered by MUA has been provided in the 2022 summary statistics document (Tree Canopy Summarised by LGA and Suburb 2022 and 2019) for reference (available on the SEED Portal dataset: Greater Sydney Region Tree Canopy to Modified Mesh Block 2022).

6 Quality Control

The department conducted an internal review of the 2022 Greater Sydney tree canopy dataset and associated findings before publication.

The review included:

- an assessment of all raster data properties to ensure consistency across products
- high level visual reviews to detect gaps and issues within and between raster datasets
- a cross check of boundaries used for analysis and reporting with internal calculations at various scales
- recalculation of a selection of modified mesh block statistics to ensure repeatability in reported results.

Foreseeable precautionary steps were taken to ensure ArborCarbon's data and results were verified correctly during the internal review process. Reported discrepancies are considered minor in nature and not significant to the overall analysis or QC process.