2018 and 2023 Vegetation Canopy Cover Measurements in the City of Whitehorse

Contents

Executive Summary

Council's Urban Forest Strategy 2021-2031 sets targets relating to the measurement of and change in tree canopy. For Council to accurately track and report on progress in meeting the Urban Forest Strategy targets, a standardised and repeatable methodology is required for Council to process datasets for reporting on canopy cover change.

Lidar is a remote sensing technology which provides a highly accurate direct measurement of tree canopy, enabling accurate quantification of canopy cover across large areas.

Canopy measurement is conducted through the acquisition and classification of a lidar point cloud, enabling accurate and consistent reporting of canopy cover over the lifecycle of the Urban Forest Strategy.

A lidar point cloud acquired in November 2017 was processed resulting in a measurement of a 21.6% canopy cover. A second lidar acquisition from December 2023 was processed and measured a 25.8% canopy cover, which represents a 4.2% increase in canopy cover over the six-year period.

Changes in canopy cover can be effectively measured using spatial datasets derived from lidar point clouds.

Introduction

Background

The Urban Forest Strategy 2021-2031 sets an urban forest vision that melds community aspirations, existing policies, and strategies to guide Council to better protect, enhance and connect Whitehorse's natural assets[1]. Objective 2 within the strategy is to '*Expand the urban forest across private and public land*', with targets to increase tree canopy to 27% by 2031 and to increase tree canopy to 30% by 2050. The strategy considers canopy as tree crown above a height of three metres.

Measurements of canopy for benchmarking and tracking purposes can be obtained using remote sensing techniques such as lidar and aerial photography. Lidar is preferred when detailed three-dimensional measurements of canopy height and structure are required.

Lidar (Light Detection and Ranging) is a remote sensing technique that uses rapid pulses of laser light to measure distance and to densely sample the surface of the Earth[2]. The lidar sensor measures the time taken for a laser pulse to travel to and reflect off the earth's surface. Each reflection becomes a measurement of the height of a surface feature, and together these reflections produce a high density point cloud with dozens of points per square metre.

This resulting high density lidar point cloud represents the base data required to generate a representation of the canopy within an area of interest.

Lidar's ability to provide three-dimensional information makes it particularly well-suited for accurate canopy height measurement as it offers a repeatable and accurate method for measuring canopy and its change over time.

Council has acquired two lidar datasets covering the full extent of the City of Whitehorse: one captured on 28 November 2017 (the '2018 lidar') and the second on 29 December 2023 (the '2023 lidar').

Measuring Urban Forest Canopy Targets

To track and report progress against the Urban Forest Strategy's targets, Council has adopted a standardised approach for canopy measurement. This approach, based on

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[1] https://www.whitehorse.vic.gov.au/waste-environment/trees-and-gardens/trees/urban-forest-strategy
[2] https://support.esri.com/en-us/gis-dictionary/lidar

classified lidar point clouds, ensures accurate, repeatable, and consistent reporting throughout the strategy's lifecycle.

Methodology

Canopy from lidar

Through the acquisition of lidar, Whitehorse City Council has followed best practice industry standards in the generation of canopy models. At a high-level, the workflow includes the steps outlined in the figure below.

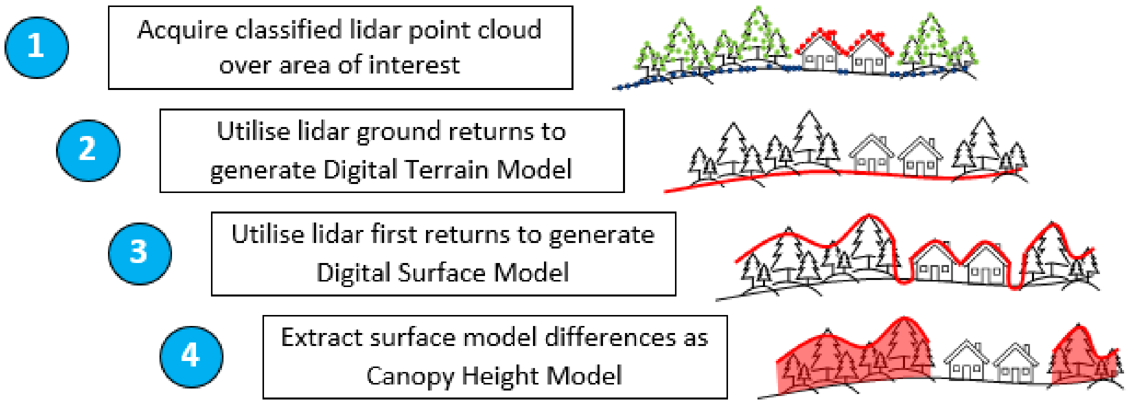

Figure 1: Best practice workflow for Canopy Height Model generation.

The Canopy Height Model produced through this workflow represents canopy heights across the full extent of the City of Whitehorse. A total canopy area is obtained by summing areas within the Canopy Height Model having a height greater than three metres.

Data Sources

Council has acquired two lidar datasets:

The '2018 lidar'	In 2018, Council participated in a collaborative purchase of lidar over Metropolitan Melbourne, including the generation of elevation models and 0.5 metre interval contours. The City of

	Whitehorse data was captured on 28 November 2017 and is referred to as the ‘2018 lidar’.
The '2023 lidar’	In 2023, Council commissioned a lidar and aerial imagery survey covering the City of Whitehorse, including the generation of elevation and vegetation models. The data, captured on 29 December 2023, is hereafter referred to as the ‘2023 lidar’.

Standardisation

The ICSM (Intergovernmental Committee on Surveying and Mapping) has established widely adopted lidar point cloud classification standards. Both of the lidar datasets referenced above are classified to ICSM Lidar Point Cloud Classification Level 2, Ground surface improvement[3].

The 2023 lidar survey commissioned by Council specified a 98% classification accuracy[4] for the vegetation lidar classes. The collaborative purchase that delivered the 2018 lidar, however, did not include improvements to vegetation classification to this level of accuracy.

In late 2024, Council funded a project to enhance the vegetation classification within the 2018 lidar, bringing it into alignment with the 98% accuracy standard of the 2023 lidar. This work included the generation of new 2018 elevation and vegetation models to the same standard as those produced for the 2023 lidar.

Council’s canopy cover analysis was undertaken using both the 2018 and 2023 lidar datasets, with ground and vegetation classes at the 98% classification accuracy level.

Analysis Approach

Raster dataset analysis is employed to generate a Canopy Height Model (CHM) by subtracting the Digital Terrain Model (DTM) from the Digital Surface Model (DSM), isolating vegetation height for subsequent canopy analysis. A raster dataset is a cell-based data model, where each cell contains a value in a matrix of rows and columns[5].

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[3] https://www.icsm.gov.au/what-we-do/elevation-and-depth-data

[4] A 98% classification accuracy means that our expectation is that 98 out of every 100 lidar points in this data will correctly represent the real-world features they depict (like ground, buildings, or trees), with a defined level of precision.

[5] https://pro.arcgis.com/en/pro-app/latest/help/data/imagery/essential-imagery-and-raster-terms.htm

For the 2018 and 2023 Canopy Height Models, the value stored in each cell represents the height of vegetation at that location, where the height has been determined from vegetation classified lidar points falling within the cell. Each cell has 0.5m sides and a real-world area of 0.25m^2. The sizing of the cell is approximately three times the average lidar point spacing, conforming to best practice.

Tree Canopy Determination

The Urban Forest Strategy considers canopy as tree crown above a height of three metres.

A typical example of the canopy determination follows, utilising a tree located at the Civic Centre Precinct.

Figure 2: Tree canopy

A Chinese Elm tree canopy photographed from the Civic Centre car park facing east.

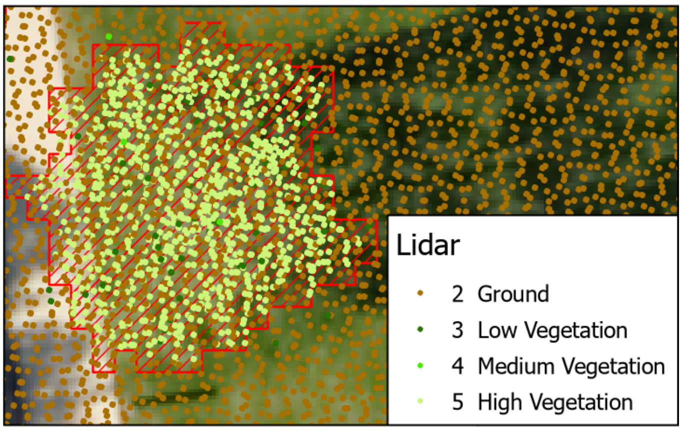

Figure 3: Lidar point cloud

Classified lidar ground and vegetation points at the Chinese Elm tree. Ground points are mixed in-between the vegetation points in areas where the lidar pulse has passed through gaps in the tree canopy. The Canopy Height Model boundary is shown in red and contains approximately 1600 lidar points of which approximately 1000 are classified as vegetation.

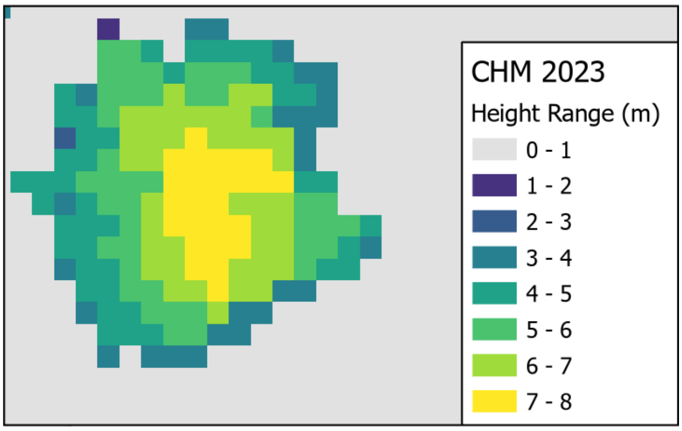

Figure 4: Canopy Height Model

The derived Canopy Height Model with height classes showing vegetation height above the ground surface.

Each cell within the derived Canopy Height Model has been assigned a height value based on the highest vegetation lidar points falling within the cell. While lidar measures vegetation at a range of heights, only cells with heights above three metres participate in the determination of canopy.

Calculating Canopy Change

To enable area-based analysis the 2018 and 2023 Canopy Height Models were converted from raster to vector formats and subsequently unioned with Council's suburb boundaries. The union operation calculates the geometric union of the input datasets while retaining all input attributes of the constituent geometries.

The total canopy for each suburb was determined by summing all Canopy Height Model geometries representing vegetation heights above 3 metres.

Tree canopy change represents the difference in canopy cover measured across the two time periods. Change is expressed both as an area in hectares (1 hectare = 10,000 square metres) and as a percentage of canopy cover.

Results

Council's 2018 Canopy Measurement

Based on the improved 2018 lidar, a canopy measurement was assessed with a total area of 1388.86 hectares, representing a canopy cover of 21.6% for the full extent of the City of Whitehorse.

Canopy Change 2018-2023

Based on the 2023 lidar, a canopy measurement was assessed with a total area of 1657.64 hectares, representing a canopy cover of 25.8% for the full extent of the City of Whitehorse. This measurement represents a 4.2% increase in canopy cover from Council's 2018 measurement.

	TOTAL AREA (ha)	2018 CANOPY (ha)	2018 CANOPY %	2023 CANOPY (ha)	2023 CANOPY %
CITY OF WHITEHORSE	6423.70	1388.86	21.6%	1657.64	25.8%

Table 1: Canopy Height Model derived canopy areas and percentage cover for full extent of City of Whitehorse.

A breakdown of the 2018 and 2023 canopy cover per suburb is listed below. These figures represent canopy taller than three metres.

SUBURB	SUBURB AREA (ha)	2018 CANOPY (ha)	2018 CANOPY %	2023 CANOPY (ha)	2023 CANOPY %	CANOPY CHANGE (ha)	CANOPY CHANGE %
BALWYN NORTH	8.89	2.12	23.8%	2.27	25.5%	0.15	1.7%
BLACKBURN	590.00	177.59	30.1%	203.26	34.5%	25.68	4.4%
BLACKBURN NORTH	268.73	53.07	19.7%	63.91	23.8%	10.84	4.0%
BLACKBURN SOUTH	359.77	69.46	19.3%	87.42	24.3%	17.95	5.0%
BOX HILL	352.15	64.35	18.3%	78.28	22.2%	13.94	4.0%
BOX HILL NORTH	396.30	72.31	18.2%	87.64	22.1%	15.33	3.9%
BOX HILL SOUTH	349.13	70.92	20.3%	86.77	24.9%	15.86	4.5%
BURWOOD	503.51	97.17	19.3%	124.57	24.7%	27.39	5.4%
BURWOOD EAST	426.22	64.20	15.1%	77.43	18.2%	13.23	3.1%
FOREST HILL	406.84	79.22	19.5%	96.11	23.6%	16.88	4.2%
MITCHAM	662.62	169.66	25.6%	194.47	29.3%	24.82	3.7%
MONT ALBERT	164.24	41.96	25.5%	49.63	30.2%	7.67	4.7%
MONT ALBERT NORTH	213.69	53.08	24.8%	63.59	29.8%	10.50	4.9%
NUNAWADING	494.74	93.04	18.8%	108.66	22.0%	15.62	3.2%
SURREY HILLS	169.91	44.00	25.9%	51.04	30.0%	7.04	4.1%
VERMONT	439.04	105.28	24.0%	123.20	28.1%	17.92	4.1%
VERMONT SOUTH	617.92	131.43	21.3%	159.39	25.8%	27.96	4.5%
CITY OF WHITEHORSE	**6423.70**	**1388.86**	**21.6%**	**1657.64**	**25.8%**	**268.78**	**4.2%**

Table 2: Canopy Height Model derived canopy areas and percentage cover per suburb.

Guidance in interpreting Table 2:

- Canopy Change % is the arithmetic difference in canopy percentage between the two dates.

  Canopy Change % = 2023 Canopy % – 2018 Canopy %

- Across the full extent of the City of Whitehorse, canopy has increased by 4.2%.

- Canopy Change % is reported over a single time period of six years and does not represent an annual change, i.e. canopy has not been increasing by 4.2% per year for each of the six years.
- The Canopy Change % per year is calculated as an average of this value over the six years, i.e. an average increase of 0.7% per year, adding to a total of 4.2% over the six-year period.

Visualising Canopy Change

Areas where canopy has increased or reduced between these two measurements have been assessed through the spatial analysis of the generated Canopy Height Models.

Canopy change can be visualised at both a micro and macro level.

Micro level

The micro level change highlights individual areas of change at the property level. Separate layers have been prepared to display canopy gain, canopy loss and areas where canopy is unchanged between these two measurements.

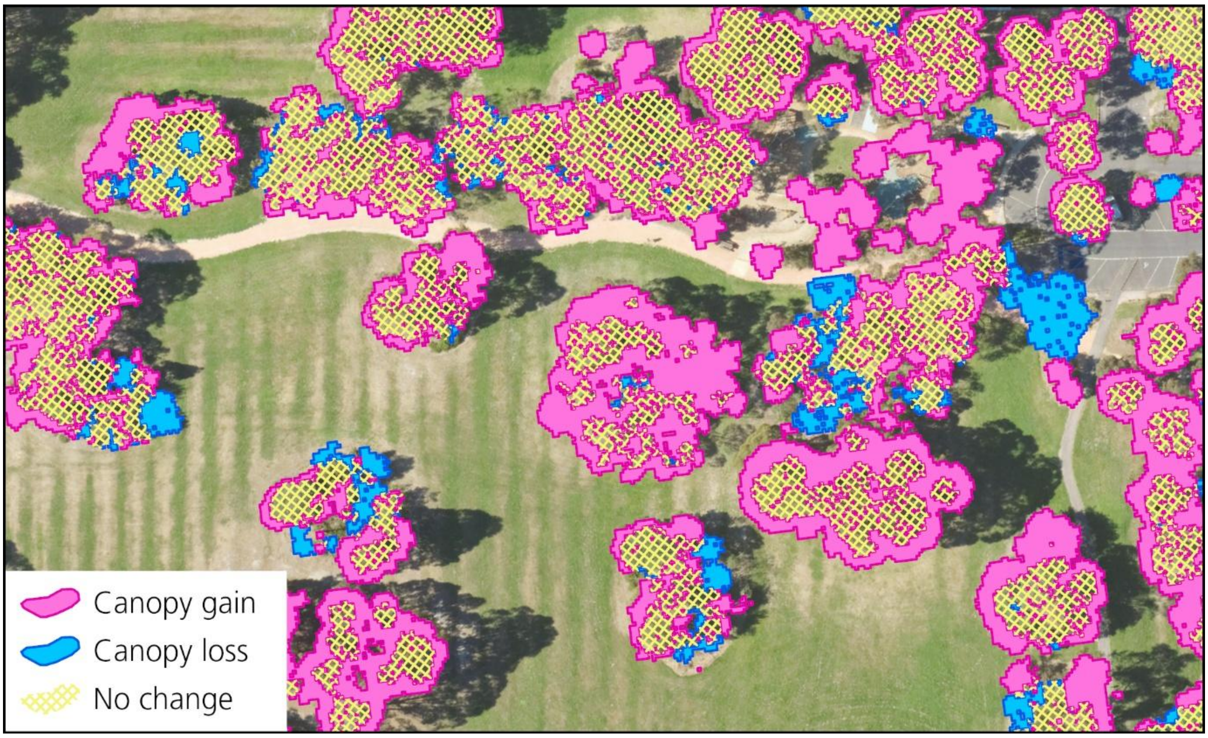

Figure 5: Canopy Change (for vegetation above 3 metres) 2018 - 2023

In the above figure, canopy gains, loss and no change are visualised at an individual tree level. Canopy loss is highlighted in blue and represents areas of canopy loss. Canopy gain is highlighted in pink and represents either new canopy or growth in existing canopy.

Macro level

The macro level change highlights change at a neighbourhood level. This is facilitated through the 'binning' of canopy features into 1-hectare hexagons. 'Binning' aggregates gains and losses and represents these as a single value for each hexagon.

Aggregating spatial data into hexagonal bins is standard practice in analysis. Hexagons provide equal-area cells and uniform adjacency, producing more consistent and reliable representations than square grids.

Visualising canopy change at the micro level creates a busy map as every individual area of gain or loss is accounted for in the dataset. Visualising canopy change at the macro level removes the high level of detail and simplifies complex changes to clearly reflect the general trend of an overall gain or loss within each 1-hectare hexagon.

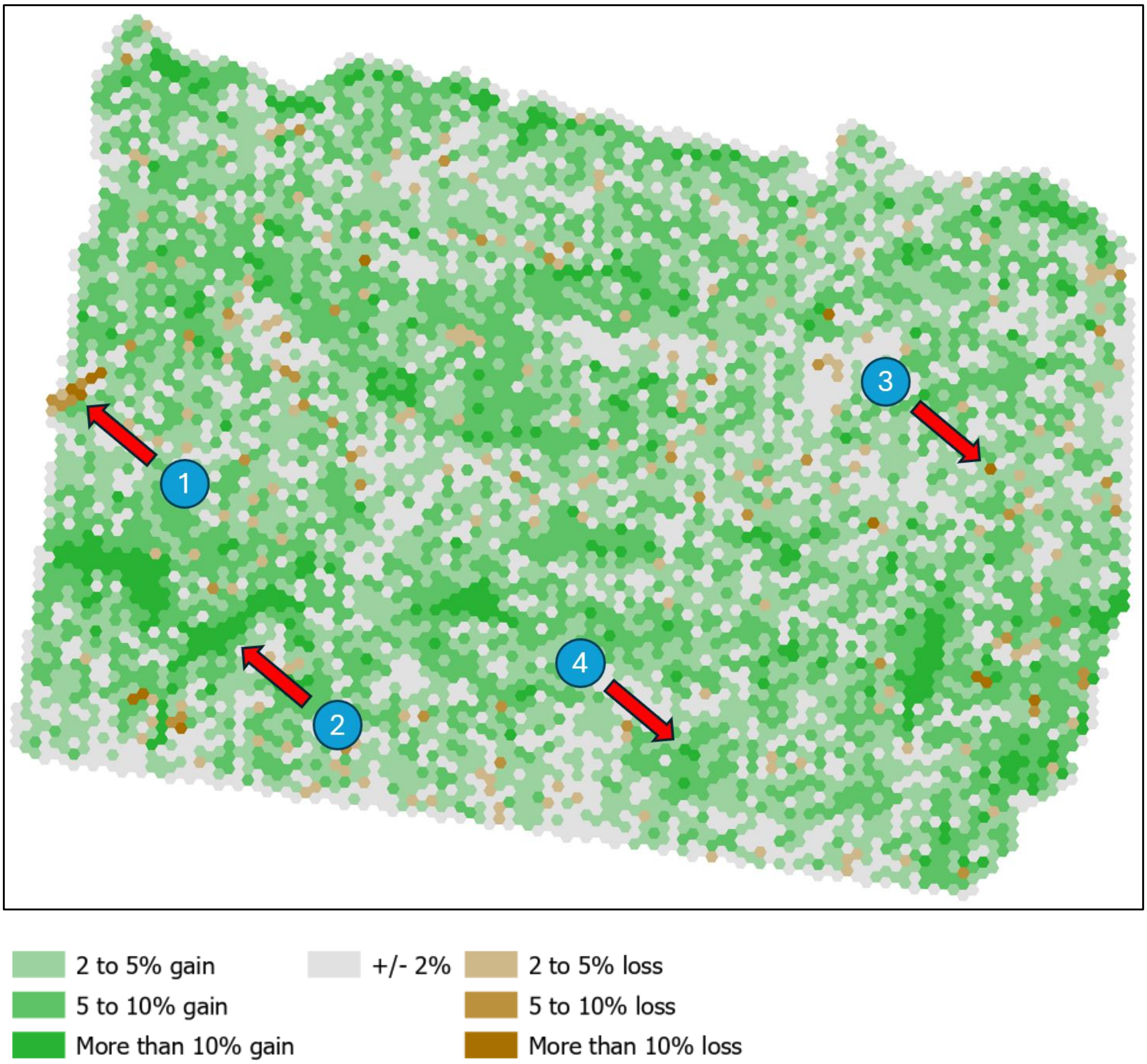

Figure 6: Macro level canopy change (2018-2023) visualised through 1-hectare bins.

In the above figure, visualisation through 'binning' identifies canopy change:

1. Broad area canopy loss in the Mont Albert area (Union Station).
2. Broad area canopy gain in the Box Hill South area (Gardiners Creek).
3. Localised canopy loss in Mitcham.
4. Localised canopy gain in Forest Hill.

Conclusions

- Council's 2018 lidar provided a measurement of canopy of 21.6%.
- Council's 2023 lidar provided a measurement of canopy of 25.8%.
- Over the six-year period, this represents an increase of 4.2% in canopy cover.
- Canopy has increased in each of Council's 17 suburbs.
- Through the visualisation of gains and losses:
    - At a macro level, using hexagon 'binning', general trends of canopy gain and loss can be identified at a neighbourhood level.
    - At a micro level, individual gains and losses can be accounted for at a property level.
    - Losses display as the result of the reduction of canopy (whole or part) on public and private land.
    - Most of the gains display as a growth of existing canopy. There are however small pockets of new growth such as those visible in Figure 5 above.

This analysis establishes an important baseline of vegetation cover for the City of Whitehorse, providing a benchmark against which progress toward urban forest canopy targets can be measured.