ACTIVE GREEN SERVICES

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Tree Canopy Benchmark Study & Thermal Imaging

Alexandrina Council

2022 Data

February 6, 2023

Tree Canopy Benchmark Study

& Thermal Imaging

Prepared for

Alexandrina Council

Year

2022

Prepared by

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Executive summary and recommendations

This report, on the Tree Canopy Benchmark Study & Thermal Imaging project, fulfills the primary purpose of the project which was to complete a "Tree Canopy Baseline Study to establish a benchmark of tree canopy cover in Alexandrina". It assesses tree canopy cover in 11 urban and peri-urban areas of Alexandrina using 2022 data. The associated, geospatially linked, web-based portal provided as part of the project includes thermal imaging, used to correlate tree canopy cover and relative radiant temperatures.

Overall tree canopy cover results for these areas was 17.6% comprised of:

- Ashbourne 49.3%,
- Clayton Bay 14.3%,
- Goolwa 14.3%,
- Hindmarsh Island 19.9%,
- Langhorne Creek 19.9%,
- Middleton 14.1%
- Milang 11.7%,
- Mount Compass 23.4%,
- Port Elliot 13.9%,
- Strathalbyn 19.4%
- Woodchester 13.1%.

Tree canopy data was further segmented on the basis of land ownership for each area, as determined by Council-supplied cadastral data. Together, such data significantly informs urban greening strategy and management for challenges such as planting site availability. Private land holdings amounted to 78.0% of the total survey area and accounted for 76.4% of the total tree canopy demonstrating the criticality of private tree canopy management to Council tree canopy strategic targets.

The methodology used was the application of high-resolution satellite imagery assessed using artificial intelligence (AI). Thermal imaging (infrared) was also acquired and correlated to the canopy layer by linking the data geospatially via an ESRI application. Clear correlation of canopy cover to radiant temperature was demonstrated across the LGA, suitable for strategic management purposes. The 2022 canopy cover benchmark and thermal imaging establishes an important data-set to help develop urban greening strategy including target planting site areas and benchmarks for future canopy gain and loss measurement.

Recommendations are discussed throughout and summarised here as follows:

- Create a tree inventory to provide critical additional data, species and life expectancy, and tree risk assessment in high traffic (occupancy) public areas
- Commission Alexandrina's *Urban Greening Strategy* using a tree inventory and this report and platform tools, to inform its recommendations and to set KPI's and targets
    - Canopy maintenance cannot be recommended as best practice in the face of climate change. Increased canopy cover should be planned for
    - Focus area one - canopy preservation and improvement by incentivising Private landholders noting that a 1% area loss of Private land as canopy would require a 20% increase in canopy cover on Council controlled landholdings
    - Focus area two - maximising social value through strategic, informed investment in tree maintenance, preservation and new tree planting
- Canopy data capture and analysis should occur biennially, as a minimum.

Contents

Sample image from Strathalbyn: canopy cover determined by AI with an overlay of geospatially linked thermal image demonstrating the relationship between canopy and radiant temperature

Background and brief

The primary purpose of this project was to complete a "Tree Canopy Baseline Study to establish a benchmark of tree canopy cover in Alexandrina".

Alexandrina Council encompasses a total land area of 1,827 square kilometres comprising rural and rural-residential, township and holiday areas.

The natural amenity of the region and its proximity to Adelaide act as significant drivers for growth. The resident population of Alexandrina Council for 2021 was 28,730, with a population density of 16.02 persons per square km. It is forecast to grow to 36,907 by 2041 (2016 census).

In recent years, population growth in Alexandrina has been well above the average for South Australia. The Council has long been a destination for retirement migrants and other life-stylers, particularly the coastal towns in the southern part of the municipality.

The Fleurieu Peninsula, of which Alexandrina Council is a part of, is expected to experience longer and hotter heatwaves in the foreseeable future. It is known that trees can help to mitigate the impacts of climate change by cooling and shading homes and streets, thereby providing indirect health benefits and reducing electricity bills.

However, in order to identify where trees should be established, preserved and restored, a baseline is required. Hence this study, which will be used to track future canopy gain and loss both on private and public land, especially in and around Alexandrina's townships.

The purpose of the study was to provide a sound, evidence-based urban tree canopy baseline of the current 'urban' tree canopy on public and private properties. This will then inform the development of Alexandrina's "Urban Greening Strategy", with the goal of increased township greening and tree planting for canopy cover in line with Alexandrina's Community Strategic Plan A2040.

Climate change is the issue of greatest concern to the people of Alexandrina. Increasingly frequent adverse events, the fragility of Alexandrina's ecosystems and the security of water supplies, led to its 2019 Climate Emergency declaration.

Urban trees are critical assets to townships and cities. Increased canopy cover help to reduce urban heat islands by providing shade and releasing water vapor, conserve energy, reduce runoff, filter stormwater, absorb pollutants, increase urban biodiversity and store carbon.

The Strategy will ultimately be delivered through the planting, preservation and restoration of trees and vegetative cover while providing flexibility to allow development, solar access, and greater tree protection.

This tree canopy baseline will form the basis for setting future management goals as part of the proposed strategy and provide benchmarks against which to measure progress in their accomplishment.

Specific objectives of this study were to benchmark existing canopy %'s for the areas of

- Strathalbyn
- Goolwa
- Hindmarsh Island
- Middleton
- Port Elliot
- Ashbourne
- Langhorne Creek
- Clayton Bay
- Milang
- Woodchester
- Mount Compass

and to introduce new data in the form of thermal imaging to help demonstrate the urban "heat island" effect and inform Council strategy with regards to topics such as:

- Tree planting priorities
- Urban design

Improved resolution satellite imagery of much of the globe is now commercially available on a regular basis. Active Green Services has been working with its satellite technology partner, LiveEO (Germany), on various potential applications of satellite imagery with regards to vegetation management in both the infrastructure and government sectors.

This current work combines and applies the latest technologies to measure and visualise tree canopy and associated radiant temperature effects. It represents a pioneering and innovative approach to urban greening management.

The 2022 canopy cover study establishes an important data-set from which to develop an Urban Greening Strategy and benchmark future canopy gain and loss. With these capabilities, the project outcomes will be used to:

- Set targets for desired tree canopy (short, medium and long-term targets)
- Identify areas of low canopy coverage and potential tree planting sites
- Inform on the effects of impervious surfaces on urban heat islands
- Inform the development of an Urban Greening Strategy
- Inform a review of the Tree Management Policy and Tree Management Procedure
- Identify regulatory gaps and programming opportunities
- Facilitate future urban tree canopy analysis and adaptive management
- Aid in the creation of an Urban Tree Inventory
- Help to educate elected and appointed officials, residents, developers, property owners, and property developers.

Long-term success will require periodic assessment of change in Alexandrina's overall canopy and application of adaptive management principles to adjust regulations, management plans and educational programs to achieve the goals that will be articulated in the proposed Urban Greening Strategy, underpinned by this study.

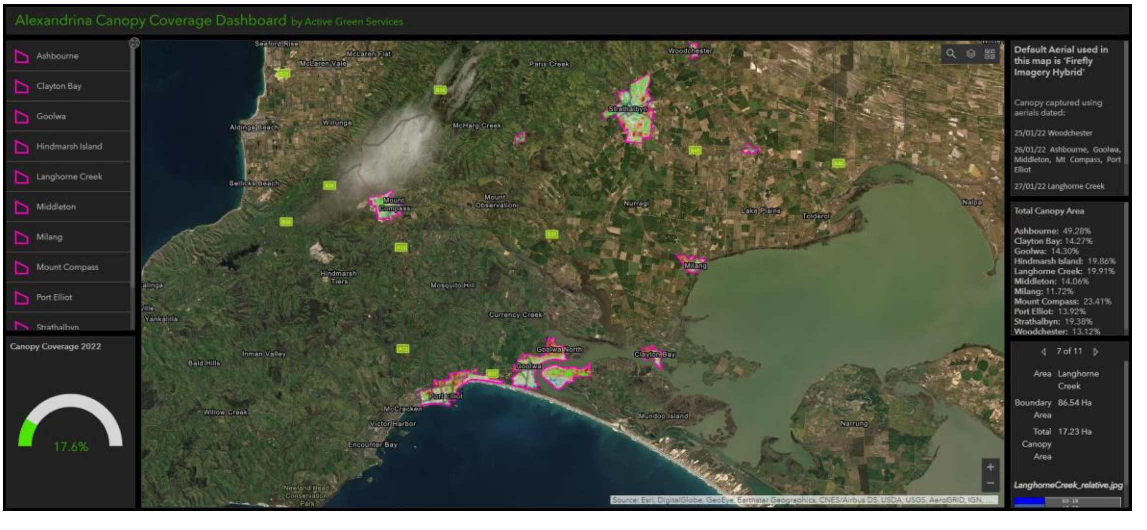
Scope

The study will:

- Analyse tree canopy according to public properties, private properties, and other institutional (agency, school) properties
- Provide data sets for a Digital Canopy Model, Canopy Coverage Map, Canopy Coverage by Unit of Area, Canopy Height Stratification Map
- Be set up so that Alexandrina can replicate the analysis with past or future aerial photo data sets for comparable analysis of tree canopy
- Contribute to a growing regional dataset on urban tree canopy (e.g. metropolitan Adelaide)
- Provide geospatial analysis data and a written analysis and synthesis of the study results with maps and management recommendations.

Results

Tree canopy and thermal image visualisations are supplied via this link:
https://mapping.active.com.au/portal/apps/opsdashboard/index.html#/a7ec0ef5ac9c47a4bd1e04c7e7203894
(password protected).



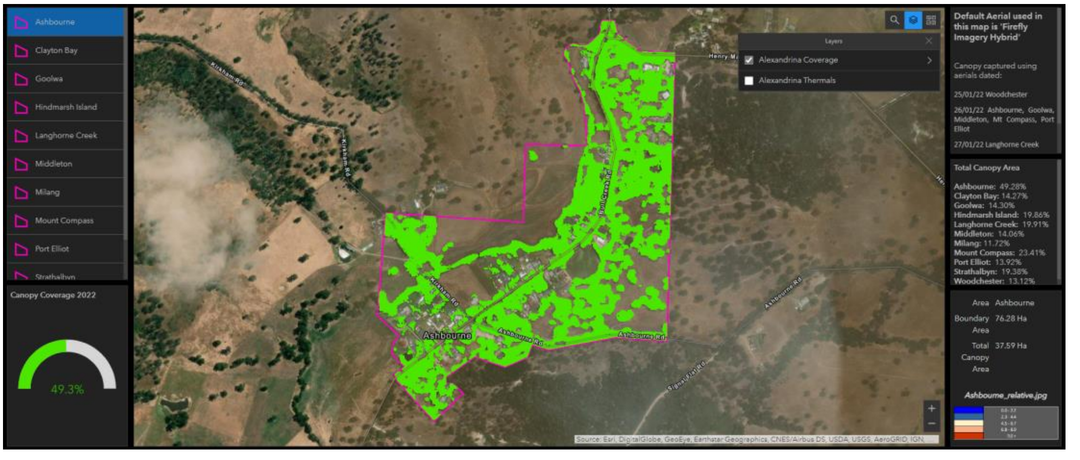
Tree canopy by landholder category is provided as a dashboard via a second link:
https://mapping.active.com.au/portal/apps/opsdashboard/index.html#/bd0edaf03cba46b28af6f128f0fa04d5
(Password protected)

The links provide access to Active Green Services ESRI platform for 12 months. The canopy and thermal image data layers are supplied for use in Council's GIS platform. The ESRI tool allows Council to zoom in to various areas on the Canopy Coverage Dashboard. In this dashboard, the canopy cover "%" shown in the bottom left "tacho" representation recalculates to the "visual extent" viewable in the central image "widget". For example, the average canopy cover for the 11 areas assessed can be seen as being 17.6%.

Area results

The Canopy Coverage display for each township follows:

Ashbourne



Clayton Bay

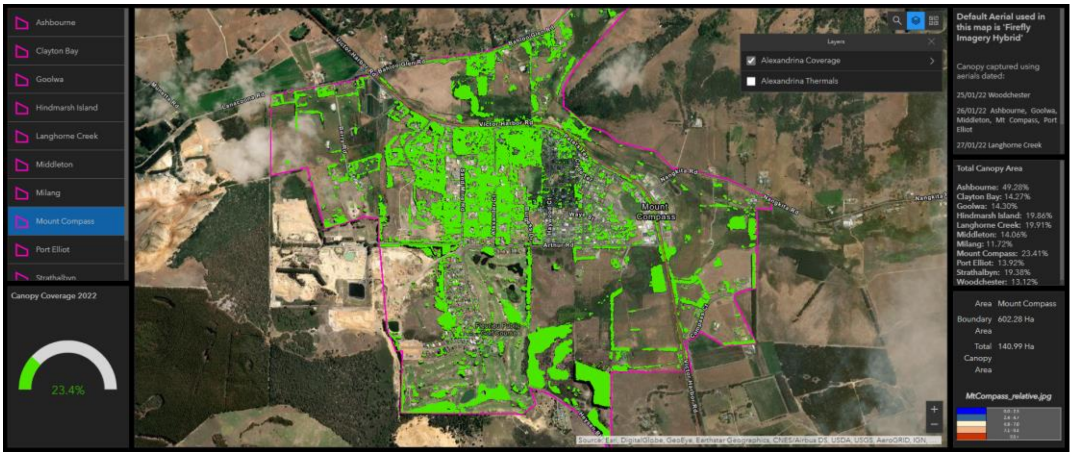
Goolwa and Hindmarsh Island

Langhorne Creek

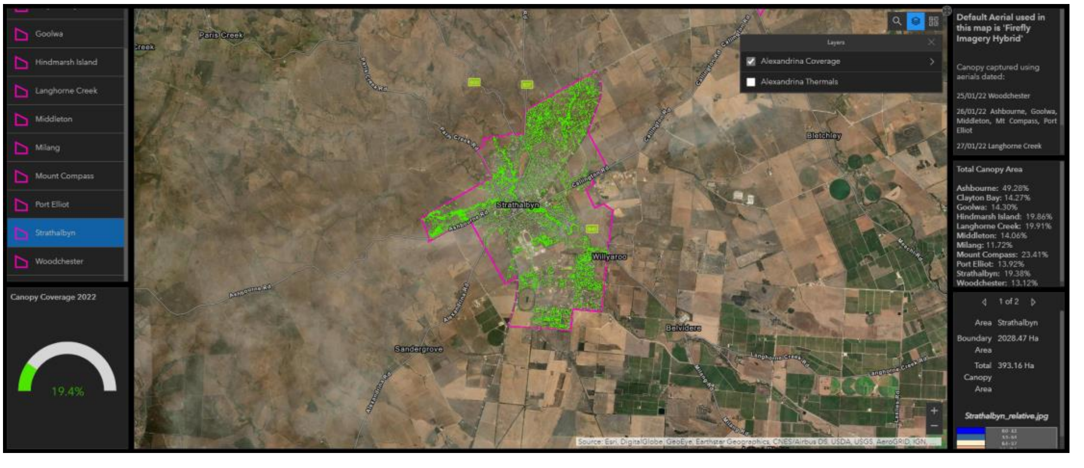
Middleton and Port Elliot

Milang

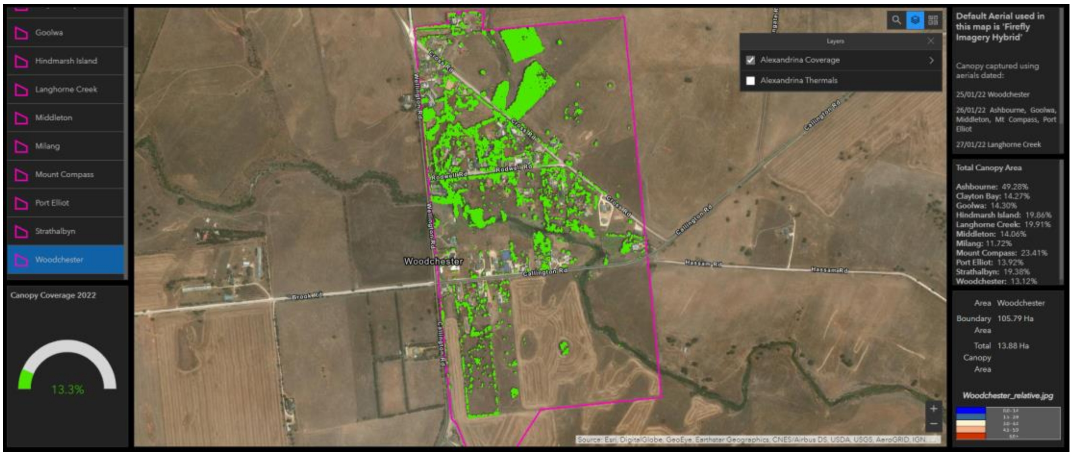
Mount Compass



Strathalbyn



Woodchester

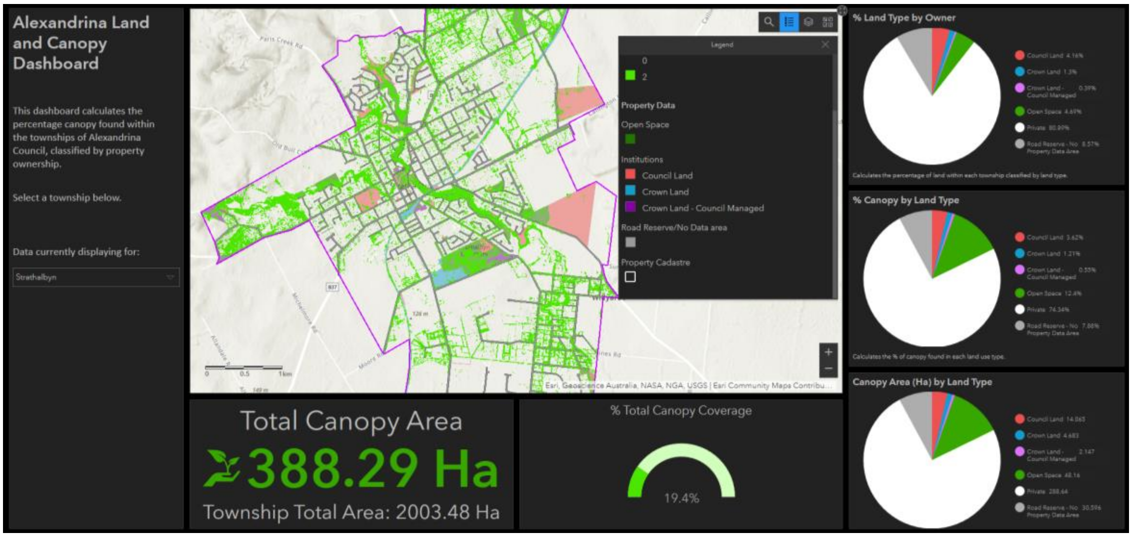


Canopy cover by township and landholder

Council's GIS team provided cadastral information via shape files for the following categories of landholder, by township:

- Council land/facilities
- Council road reserves
- Council open space reserves
- Council managed Crown land
- Crown land
- Private

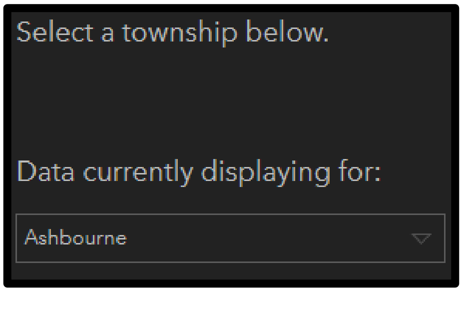
Canopy data was then assessed against this data and presented via a second dashboard:



Land and Canopy Dashboard example for Strathalbyn

This dashboard incorporates township-specific area and canopy data, and pie chart widgets showing the proportions of area and canopy by: i. % Land Type by Owner, ii. %Canopy by Land Type, and iii. Canopy Area (Ha) by Land type. A table with detail follows.

The township of interest must be selected from the left hand drop down.



Note that the error band for at the town level is estimated at + / - 3% at the 95% confidence level.

Canopy cover by township and landholder (1):

By Township by land category	Area (Ha)	Canopy (Ha)	Canopy (%)	Canopy of total (%)	Area of total (%)
All Townships					
Of assessed Townships	6,540.39	1,149.66	**17.58%**	100.00%	100.00%
Council land/facilities	211.76	33.04	**15.60%**	2.87%	3.24%
Council Road reserves	693.48	97.42	**14.05%**	8.47%	10.60%
Council Open space reserves	405.35	117.20	**28.91%**	10.19%	6.20%
Council managed Crown land	59.84	13.20	**22.06%**	1.15%	0.91%
Council subtotal	1,370.43	260.86	**19.03%**	22.69%	20.95%
Crown land	67.62	10.46	**15.47%**	0.91%	1.03%
Private land	5,102.34	878.35	**17.21%**	76.40%	78.01%
Ashbourne					
Of assessed Township	75.31	37.12	**49.29%**		
Of all Townships				0.57%	1.15%
Council land/facilities	0.08	0.02	**24.14%**	0.05%	0.11%
Council Road reserves	7.09	5.00	**70.55%**	13.52%	9.41%
Council Open space reserves					
Council managed Crown land					
Council subtotal	7.17	5.02	**70.02%**	13.57%	9.52%
Crown land					
Private land	68.14	32.10	**47.11%**	86.43%	90.48%
Clayton Bay					
Of assessed Township	235.90	33.66	**14.27%**		
Of all Townships				3.61%	0.51%
Council land/facilities	2.55	0.59	**23.16%**	1.76%	1.08%
Council Road reserves	28.97	3.21	**11.08%**	9.55%	12.28%
Council Open space reserves	26.23	2.42	**9.23%**	7.18%	11.12%
Council managed Crown land	1.34	0.15	**11.16%**	0.45%	0.57%
Council subtotal	59.09	6.37	**10.78%**	18.94%	25.05%
Crown land	0.21	0.12	**56.52%**	0.34%	0.09%
Private land	176.59	27.17	**15.39%**	80.71%	74.86%
Goolwa					
Of assessed Township	1,160.77	166.02	**14.30%**		
Of all Townships				17.75%	2.54%
Council land/facilities	31.75	4.55	**14.33%**	2.74%	2.74%
Council Road reserves	172.37	17.99	**10.44%**	10.84%	14.85%
Council Open space reserves	80.09	22.55	**28.15%**	13.58%	6.90%
Council managed Crown land	9.75	2.10	**21.54%**	1.26%	0.84%
Council subtotal	293.97	47.19	**16.05%**	28.42%	25.33%
Crown land	14.80	2.46	**16.62%**	1.48%	1.28%
Private land	852.01	116.37	**13.66%**	70.09%	73.40%

* Looking at a scenario where and area of tree canopy is lost equal to 1% of Private land (51 Ha), the Canopy % on Private land would reduce from 17.21% to 16.21%. To replace this canopy loss (51 Ha) on land owned or controlled by Council (all other categories excluding Crown land) would require an uplift in canopy cover from an average of 19.03% to 22.76% - a 20% increase on existing canopy.

Canopy cover by township and landholder (2):

By Township by land category	Area (Ha)	Canopy (Ha)	Canopy (%)	Canopy of total (%)	Area of total (%)
Hindmarsh Island					
Of assessed Township	739.72	146.89	**19.86%**		
Of all Townships				11.31%	2.25%
Council land/facilities	44.05	3.34	**7.58%**	2.27%	5.96%
Council Road reserves	57.25	6.66	**11.63%**	4.53%	7.74%
Council Open space reserves	14.20	3.37	**23.73%**	2.29%	1.92%
Council managed Crown land	1.63	0.34	**20.89%**	0.23%	0.22%
Council subtotal	117.14	13.71	**11.70%**	9.32%	15.84%
Crown land	0.78	0.02	**2.64%**	0.01%	0.11%
Private land	621.81	133.16	**21.41%**	90.66%	84.06%
Langhorne Creek					
Of assessed Township	85.49	17.02	**19.91%**		
Of all Townships				1.31%	0.26%
Council land/facilities	0.35	0.08	**22.82%**	0.45%	0.41%
Council Road reserves	10.34	1.52	**14.71%**	8.90%	12.09%
Council Open space reserves	3.35	2.11	**62.96%**	12.42%	3.92%
Council managed Crown land	0.03	0.02	**88.93%**	0.13%	0.03%
Council subtotal	14.06	3.73	**26.54%**	21.91%	16.45%
Crown land					
Private land	71.43	13.29	**18.61%**	78.09%	83.55%
Middleton					
Of assessed Township	260.12	36.55	**14.05%**		
Of all Townships				3.98%	0.56%
Council land/facilities	0.60	0.09	**15.04%**	0.25%	0.23%
Council Road reserves	53.27	3.99	**7.49%**	10.90%	20.48%
Council Open space reserves	40.29	7.37	**18.29%**	20.16%	15.49%
Council managed Crown land	5.10	0.03	**0.65%**	0.09%	1.96%
Council subtotal	99.26	11.48	**11.57%**	31.40%	38.16%
Crown land	3.88	0.66	**17.03%**	1.81%	1.49%
Private land	156.98	24.41	**15.55%**	66.79%	60.35%
Milang					
Of assessed Township	313.20	36.71	**11.72%**		
Of all Townships				4.79%	0.56%
Council land/facilities	0.28	0.03	**11.72%**	0.09%	0.09%
Council Road reserves	37.46	4.64	**12.39%**	12.64%	11.96%
Council Open space reserves	28.97	5.32	**18.36%**	14.48%	9.25%
Council managed Crown land	23.68	8.31	**35.10%**	22.65%	7.56%
Council subtotal	90.39	18.30	**20.25%**	49.86%	28.86%
Crown land	11.68	1.20	**10.27%**	3.26%	3.73%
Private land	211.13	17.21	**8.15%**	46.88%	67.41%

Canopy cover by township and landholder (3):

By Township by land category	Area (Ha)	Canopy (Ha)	Canopy (%)	Canopy of total (%)	Area of total (%)
Mount Compass					
Of assessed Township	594.41	139.15	**23.41%**		
Of all Townships				9.09%	2.13%
Council land/facilities	6.24	1.55	**24.83%**	1.12%	1.05%
Council Road reserves	43.63	11.10	**25.44%**	7.98%	7.34%
Council Open space reserves	11.53	3.24	**28.10%**	2.33%	1.94%
Council managed Crown land					
Council subtotal	61.40	15.89	**25.88%**	11.43%	10.33%
Crown land	0.36	0.26	**72.90%**	0.18%	0.06%
Private land	532.65	123.00	**23.09%**	88.39%	89.61%
Port Elliot					
Of assessed Township	967.49	134.54	**13.91%**		
Of all Townships				14.79%	2.06%
Council land/facilities	42.47	8.72	**20.53%**	6.48%	4.39%
Council Road reserves	105.46	11.96	**11.34%**	8.89%	10.90%
Council Open space reserves	106.71	22.66	**21.23%**	16.84%	11.03%
Council managed Crown land	9.67	0.09	**0.93%**	0.07%	1.00%
Council subtotal	264.32	43.43	**16.43%**	32.28%	27.32%
Crown land	9.87	1.06	**10.74%**	0.79%	1.02%
Private land	693.30	90.05	**12.99%**	66.93%	71.66%
Strathalbyn					
Of assessed Township	2,003.48	388.29	**19.38%**		
Of all Townships				30.63%	5.94%
Council land/facilities	83.34	14.06	**16.87%**	3.62%	4.16%
Council Road reserves	171.70	30.60	**17.82%**	7.88%	8.57%
Council Open space reserves	93.96	48.16	**51.25%**	12.40%	4.69%
Council managed Crown land	7.81	2.15	**27.52%**	0.55%	0.39%
Council subtotal	356.82	94.97	**26.62%**	24.45%	17.81%
Crown land	26.05	4.68	**17.97%**	1.21%	1.30%
Private land	1,620.61	288.64	**17.81%**	74.34%	80.89%
Woodchester					
Of assessed Township	104.50	13.71	**13.12%**		
Of all Townships				1.60%	0.21%
Council land/facilities	0.04	0.002	**4.78%**	0.02%	0.04%
Council Road reserves	5.95	0.75	**12.61%**	5.51%	5.69%
Council Open space reserves					
Council managed Crown land	0.83	0.007	**0.85%**	0.05%	0.79%
Council subtotal	6.81	0.76	**11.14%**	5.57%	6.52%
Crown land					
Private land	97.69	12.95	**13.26%**	94.43%	93.48%

Methodology

The methodology used was:

- Acquire high resolution (50 cm^2) satellite imagery
- Assess 100% of the area using Artificial Intelligence (AI) to interpret and determine temporal canopy cover
- Audit and adjust - the AI assessment of mapped coverage is visually inspected by a Cert V arborist. The AI model is adjusted and manual corrections applied as required
- A thermal image was acquired with the reported temperatures adjusted to a zero point for referencing purposes
- Cadastral data, categorised by landholder type, was provided by Council
- AI interpreted canopy, thermal image and cadastral data were integrated into the ESRI ArcGIS platform for presentation,

Raw satellite imagery with 50 cm^2 ground resolution was collected from the Pleiades project in January and February, 2022. Multiple frequency bands were utilised. Tree canopy was determined though AI. In this case, a Convolutional Neural Network (CNN) machine learning model was designed and trained. CNN is an advanced AI architecture which solves computer vision tasks. It's commonly found in technologies such as autonomous vehicles and facial recognition. (See appendices for further detail.)

Data was then processed using in-house GIS and mapping applications to verify coverage, overlap and spatial accuracy. Once accuracy and coverage was confirmed, all data layers are brought into the ESRI ArcGIS application, audited and presented via web-based links. The "Canopy Coverage Dashboard" provides dynamic, interactive capabilities including measuring canopy cover flexibly to the "visual extent" (what's on screen) and is geospatially aligned to the thermal image. The thermal image was taken by Landsat 8 in February, 2022 with data acquired in two infrared spectral bands at 100m spatial resolution and rasterized to 30m for display. (See appendices for detail.)

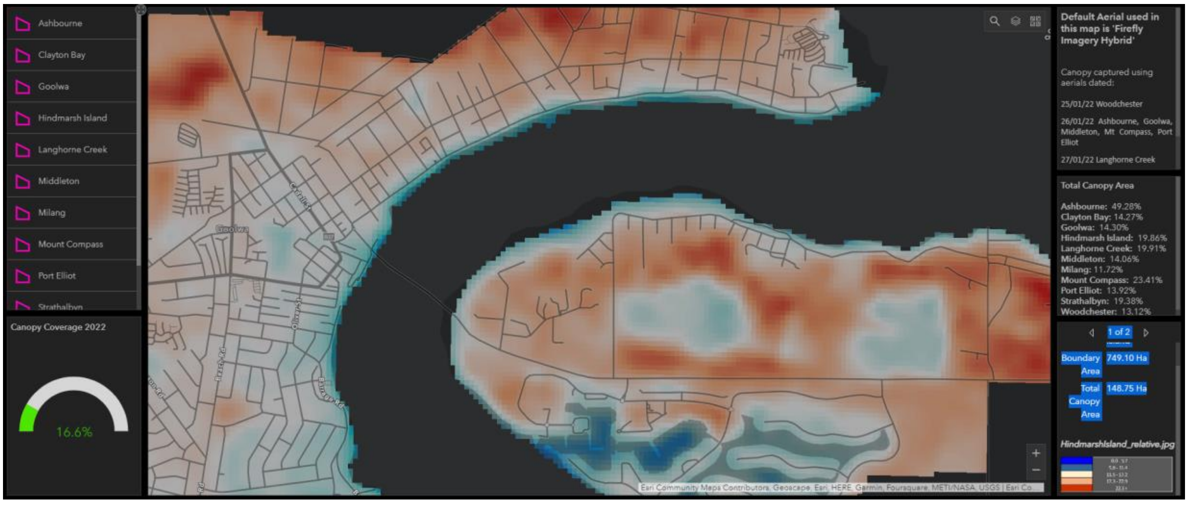
A "Land and Canopy Dashboard" overlays and analyses the canopy cover based on the cadastral information from Council's GIS team, to provide analysis by landholder type.

Key advantages for AI over existing data acquisition and analytical methods (manual field collection, i-Tree and Vegetation Index-based) are:

- 100% of an area is sampled
- 100% of an area is mapped for visual interpretation and management execution
- Date-specific sampling optimises canopy capture and enable future comparisons
- Geospatial identification and positioning, for future canopy gain and canopy loss
- Practical visualisation of all data for efficient ground-truthing
- Elimination of variability due to limited area sampling or human misinterpretation
- Cost

Together, this management information can then help inform Council officers' decisions and recommendations. The ability to both focus resources and facilitate positive change in the management of tree canopy cover by Council is greatly enhanced.

Thermal imaging – radiant temperature visualisation



Sample image demonstrating the variation in radiant temperatures across parts of Goolwa and Hindmarsh Island. By turning on and off various layers in the ESRI platform, the effect can be highlighted, and then compared to the presence of water bodies, canopy and other features.

Relative radiant temperature visualisation informs on the effects of impervious surfaces on urban heat islands and the impact of tree canopy. It is presented in the ESRI ArcGIS weblink such that it zooms and geolocates with the canopy cover and visual images. In this way, the typical correlation between tree canopy and relatively cooler radiant temperatures is clearly demonstrated and sites of concern and/or opportunity (tree planting priority sites, for example) can be identified.

Important to note is that radiant temperatures are not air temperatures. Satellite sensing is typically done at night. Radiant heat is measured as infrared spectral intensity and expressed as temperature mathematically, through prior research using controlled experiments correlating the influence of surface temperatures on perception of heat by a collective of people.*

One learning from the tool is that the relative radiant temperature of open parks and fields can be high compared to treed areas, and not dissimilar to lightly treed urban areas.

Also to note, whilst large buildings and industrial parks generally show higher radiant temperatures than surrounding areas, “anomalies” in thermal images are well known where these sometimes appear cooler. There are two causes:

1. The roof space may be genuinely cooler due to refrigeration/air conditioning; and/or
2. Emissivity - the emissivity of the surface of a material is its effectiveness in emitting energy as thermal radiation. Particular rooves may have a relatively low radiant temperature (appear cooler) due to their design and materials.

Reference:

* Kántor, N., Unger, J. (2011) The most problematic variable in the course of human-biometeorological comfort assessment - the mean radiant temperature. Cent.eur.j.geo. 3, 90–100.

Comparative data for strategy establishment and execution

In line with the purpose of this study, the acquisition of fit-for-purpose data is a fundamental management requirement in providing the evidential basis for urban greening canopy strategy development, monitoring and evolution. Without it there cannot be suitable benchmarks, targets or measures of success.

This report represents the application of the latest technology to generate, for the first time, data sufficiently granular, accurate and precise to help inform and facilitate the development of an effective urban greening strategy, particularly with the challenges that climate change represents.

Comparing existing canopy cover to other LGAs

The overall canopy cover for the 11 areas is 17.6%, the 2022 baseline canopy cover. Most of Alexandrina township's canopy cover is in range from 11.7% to 19.8% with Ashbourne having a particularly high canopy cover of 49.2%.

Active Green Services (AGS) has had the privilege of working with a number of LGA's around Australia on canopy cover and urban greening strategy. There is no published data or overarching government policy discussing the township (urban and peri-urban) areas within regional LGA's, There are benchmark studies covering urban areas, albeit that they use now-dated technology and imagery in their assessments, links here:

https://www.greenerspacesbetterplaces.com.au/media/163038/whereareallthetrees_report-final_rebranded_web.pdf

https://www.greenerspacesbetterplaces.com.au/guides/where-will-all-the-trees-be/

We have compared some potentially similar LGAs to help compare Alexandrina in terms of current canopy cover; also, what strategic goals others set. With reference to the base-line canopy cover of 17.6%, Alexandrina compares favourably to some regional LGA's such as Forbes, Cowra, Oberon, Blayney and Bathurst, all exhibiting less than 10% canopy cover. Shepparton quotes a range of 18-33% canopy cover for their township areas, for example.

Whilst the baseline canopy cover appears relatively strong, some canopy loss in Alexandrina is clear to see from the limited satellite imagery reviewed. This implies a need to address the challenges of tree removal on private land which constitutes 78% of the

The challenge of canopy loss from private land is supported by the loss of canopy recently reported by a study that analysed the changes in residential tree canopy across 281 suburbs in Adelaide. It found that canopy cover in 2021 was 18.3%, down from 20.1% in 2011, an 8.6% drop (media-published commercial research by Nearmap, 2022).

Comparative future canopy cover targets

There is currently no standard benchmark target for urban tree canopy cover in Australia or internationally, despite a 30% target coming up relatively frequently in Australian LGA's. A large UK study suggests setting a benchmark of 20% but recommends areas with less than 20% cover should commit to increasing extents by a minimum of 5% within 10-20 years, which is certainly a good starting point for low canopy cover areas. The City of Melbourne and several others (Ballarat and the City of Greater Shepparton, for example, which also contain significant tracts of rural landscape) quote a target of 40%. In the case of Greater Shepparton, this target is for 2037, not 2050 as with other LGAs with ambitious targets.

Living Melbourne – our Metropolitan Forest: https://livingmelbourne.org.au/ describes an agreed approach to increasing tree cover between the City of Melbourne and an array of councils in the Greater Melbourne area. The document suggested that targets in rural areas should be ambitious (20-30%) because, at 30% tree and understory cover, there are significant benefits for biodiversity. In a similar vein but with a different approach, Maitland shire targets canopy maintenance and improvement to foster linkages in specific biodiversity corridors. The Living Melbourne document recommended that in regional areas at least 30% of canopy increases should occur in the private landscape.

It's arguable that some of these canopy targets are "halo effect", i.e. once one LGA sets a target, others tend to follow or want to exceed it. The risk in many urban greening strategies is that there is insufficient "how to deliver" strategy with realistic programs, timings and budget estimates. This is even more-so the case when it comes to strategies for encouraging tree planting on private land.

There are examples of LGA's improving canopy cover in council-controlled areas yet suffering reduced canopy overall due to losses on private land. It is essential that an urban greening strategy addresses all land uses. For example, the City of Whittlesea's UFS breaks targets down into targets for public landscape and for private landscape. The City is currently on 19.71% and has a target of increasing cover by 20% by 2040 but focuses mostly on established and growth suburbs with only a 3% target increase for rural areas.

Few rural councils focus on developing Urban Greening Strategies and setting canopy targets in regional areas. One example is the Urban and Rural Forest Strategy (2018-2028) for the Shire of Serpentine-Jarrahdale which is an LGA 45km from Perth, 905km^2 in area. Their strategy broke the region down into urban, peri-urban and the rural landscape but the canopy goals they set were to maintain current extents via no net loss only (urban 16%, peri-urban 21% and rural 12.5%). Simple canopy maintenance as a target cannot be recommended as best practice in the face of climate change.

Establishing Strategy

Active Green Services has had the privilege to work with a number of Local Government Areas (LGAs) and institutions across Australia. The following observations are provided to inform and guide a discussion on "next steps" for Alexandrina's Urban Greening Strategy.

Key to good strategy is to define the outcomes expected. In terms of an urban greening strategy, these can be summarized as:

- Forecast canopy/Canopy cover target per year per nominated area
- Forecast budget
- Planned activity set, with demonstrable connectivity to the strategic goals
- Measured lead and lag KPI's aligned to the activities and their outcomes

Documents to assist in the development of strategy are beginning to become available. Recent examples are "How to grow an urban forest" (Greener Places Better Spaces, CoM, DELWP) which describes 10 steps culminating in an implementation plan:

https://www.greenerspacesbetterplaces.com.au/guides/how-to-grow-an-urban-forest/

and "Which Plant Where" which details the elements of life-cycle management:

(Griffiths G, Esperon-Rodriguez M, Rymer PD, Power SA, Tjoelker MG, Staas L, (2021) Best practice guideline for monitoring urban forests. Western Sydney University, Macquarie University)

https://cms.whichplantwhere.com.au/app/uploads/2021/12/7.-WPW_Measure-your-Urban-Forest-081221.pdf

Despite these contributions to the field, LGA's typically work with third party providers to create their urban greening strategy as "one time" expertise across a number of disciplines is necessary to create the strategy and accompanying documentation. With the caveat that the scope for the development of an urban greening strategy is the purview of Council, what follows here is an approach developed in the context of a typical scope.

A. Inputs and analysis

- Existing council and community values via programs of internal and external engagement; and review of existing plans, policies, and strategies

- Canopy cover and thermal imagery (identifying opportunities for canopy expansion including overlaying of thermal data and hot spot correlations and other available spatial datasets to identify where the benefits of trees are lacking)

- Tree inventory data, reporting on the state of the existing tree population including correlations between species and condition, age, and useful life expectancy

- Social needs, e.g. tourism, institutions, population, recreation and pedestrian:
    - Amenity:
        - Visitation
        - Commercial
        - Placemaking
        - Balancing and softening the built environment
    - Health, wellbeing and social interaction
    - Sun protection, shade and cooling

Honour Avenue, Macedon VIC

- Landscape character via interrogation of tree inventory data and ground-truthing

- Evaluation of ecosystem benefits provided by the current tree population:
    - Ecosystem services, e.g. carbon storage and sequestration
    - Habitat
    - Biodiversity corridors

- Opportunity for enhancement of tree assets such as identifying planting sites and potential areas for building or connecting canopy, i.e. biodiversity corridors

- Canopy trajectory history to identify patterns of canopy change, specifically canopy loss and relative threats to the existing canopy extent

- Set the planning horizon, e.g. 2050, and key milestones, e.g. 2030, 2040 and 2050

- Canopy mapping to model canopy targets and shade, and forecast tree planting requirements to achieve targets against the timeframes and milestones.

B. Strategic and planning outputs

Urban Greening Strategy (comprehensive tree inventory data and analysis)

For the most comprehensive urban greening strategy, a high degree of knowledge of the condition of existing trees, i.e. a detailed tree inventory and analysis, is required. With that, the following outputs should be sought:

- Strategy to improve age and species diversity of the urban trees while respecting biodiversity and maintaining use of appropriate locally native species
- Identification of actions to enhance the health of the existing and future urban greening including plant health care treatments and establishment maintenance program recommendations
- Tree planting requirements (numbers, species/tree types) to reach canopy cover targets with identification of tree planting priorities
- Identification of appropriate planting sites, including Water Sensitive Urban Design (WSUD) treatments suitable, based on priorities and constraints to achieve canopy targets and maximise public benefit
- WSUD and Integrated Water Management (IWM) principles and recommendations including conceptual designs
- Ecosystem services of the modelled canopy targets and comparisons with the relative services offered by the existing population
- Species selection guide
- Tree planting strategies including canopy cover maps and species palettes
- Criteria for a significant tree register and identification of suitable trees for inclusion
- Strategies for promotion of the urban greening and community education including citizen science opportunities, tree care partnerships, e.g. Adopt a tree program
- Measures to improve tree protection
- Development Control Plans (DCPs) and other planning control strategies for private and public landscapes including deep soil planting, landscaping requirements, tree retention requirements and offsets, and other best practice controls including vignettes/renders of canopy building design treatments recommended for new residential developments
- Recommendations for developer contributions to fund aspects of urban greening
- Identification of funding opportunities (incentives, grants) for urban greening enhancements, especially the increase of canopy cover on private land
- Resource requirements to deliver the strategy and budget forecasts
- Measured lead and lag Key Performance Indicators (KPIs) aligned to the activities and their outcomes
- Identifications of ways the strategy can integrate with emergency/disaster management requirements and mitigation options for the rural/urban interface

Urban Greening Strategy (limited tree inventory data and/or analysis)

Where there is limited tree tree inventory data and/or analysis informing the condition of existing trees, a strategy document can nonetheless be developed, including:

- General strategies to enhance the health of the existing and future urban greening including plant health care treatments and maintenance program recommendations
- Tree planting requirements (numbers, species/tree types) to reach canopy cover targets (excluding private land) with identification of tree planting priorities
- Desktop identification of appropriate planting sites to achieve canopy targets and maximise public benefit
- WSUD and IWM principles and recommendations including conceptual designs
- Species selection guide
- Tree planting strategies including canopy cover maps and species palettes
- Criteria for a significant tree register and identification of suitable trees for inclusion
- Strategies for promotion of urban greening and community education including citizen science opportunities, tree care partnerships, e.g. Adopt a tree program
- General measures to improve tree protection
- DCPs and other planning control strategies and recommendations for private and public landscapes including deep soil planting, landscaping requirements, tree retention requirements and offsets, and other best practice controls including vignettes/renders of canopy building design treatments recommended for new residential developments
- Recommendations for developer contributions to fund aspects of urban greening
- Identification of funding opportunities (incentives, grants) for urban greening enhancements, specifically to build canopy on private land
- Resource requirements to deliver the tree planting strategy, and budget forecasts
- Measured lead and lag KPI's aligned to the activities and their outcomes

A link to an example of an urban greening strategy document based on limited tree inventory data is here:

https://www.sunshinecoast.qld.gov.au/Council/Planning-and-Projects/Council-Plans/Street-Tree-Master-Plan

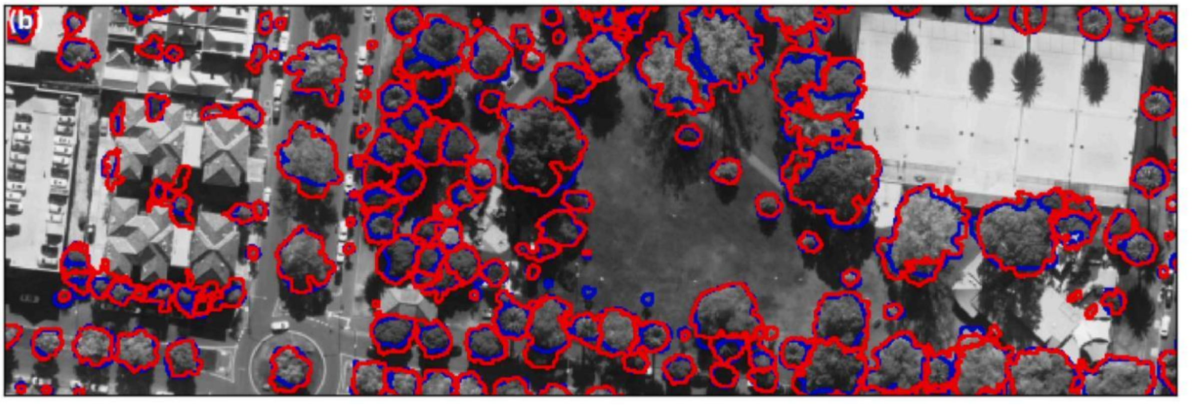
The Sunshine Coast *Street Tree Master Plan* defines a set of regional planting priorities based on in-house collected vacant planting site data. Recent advances in remote sensing technology mean that potential planting sites can now be determined more efficiently (albeit still requiring ground-truth confirmation). The Sunshine Coast program was seen as a very successful. Each Councilor holds free tree days for their respective divisions several times a year as a way of promoting the plan as well as encouraging tree planting on private land.

There is cost and time attached to each exercise in both data acquisition and in the development of strategic and planning documentation.

Species populations and maturity (typically assessed via ULE - useful life expectancy) are important parameters in determining elements of an urban greening strategy. Detailed tree inventory data has traditionally been collected particularly in city and urban environments with relatively high population densities to inform the timing and extent of planting required to replace existing canopy. Historically, these have been in-field exercises requiring extensive man-hours and incurring high cost.

Hence, the option to establish an Urban Greening Strategy on a much smaller tree inventory based on specific areas being sampled is a worthy consideration.

A new development to enhance the ongoing management of trees and tree canopy in the urban setting, particularly including trees on private land, is a "virtual" tree inventory derived from high resolution satellite imagery using AI. The first AI-based, "virtual" tree inventory work was published by Wallace et al (2021):



Whilst this capability has not yet been deployed by any LGA in Australia, it represents the only effective way to create a tree inventory, albeit limited in individual tree data, of trees on private land (along with public land). This, in turn, would greatly facilitate the management of trees in this critical landholding category.

Such an innovation would greatly enhance the evidential basis of any Urban Greening Strategy.

C. Presentation and ongoing management framework

An urban greening strategy developed in response to the inputs and analysis should succinctly present the evidence, discuss key issues, and make recommendations for enhancement of the tree canopy cover via the development of actions and a framework for implementation.

Strategy and planning documents should be presented in a customary strategy format including:

- Background and context including description of the council area and its townships, the benefits of trees and objectives of the urban greening strategy
- Strategic context. How the Strategy aligns with other, relevant tree and climate impact management documents
- Discussion of key issues within the council area and its townships and threats to its urban trees (local issues such as biodiversity population forecasts and natural disaster risk as well as universal issues such as urban heat, climate change and principles of species diversity and population resilience)
- The evidence (results of analysis)
- Strategy principles, targets, and future directions
- Action plan
- Implementation framework
- Ongoing monitoring and maintenance framework

"The Avenue", Echuca Primary School
Echuca VIC

The ongoing management framework should include:

- The measurement and reporting of lead and lag KPI’s, e.g.:
  - Canopy data recapture, measurement and analysis
    - Minimum recommended frequency - every five years; or
    - Biennially or annually, facilitating “short interval control”: best practice, granular canopy loss and gain identification at the tree level
- Commitment and resource provision for taking action to correct KPI deviations
- Annual reporting

One key requirement for the implementation of the Urban Greening Strategy is adequate funding.

Data use advances

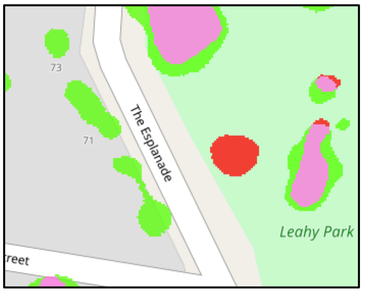
Artificial Intelligence application to high resolution satellite or low altitude imagery of tree canopy now allows the relatively cost-effective identification of individual trees across wide areas. This heralds a series of potentially new approaches to urban greening management, particularly where data is acquired annually so that year on year comparisons can be made. The following information was presented at TreeNet in 2021.

Development impact – canopy loss can be visualised (red) and calculated.

Spit Road, Mosman NSW

Tree removal and hazard tree identification

Comparing data layers in a GIS system allows visualisation of dead or removed trees, represented by the read “dot” in this example from Mosman LGA.



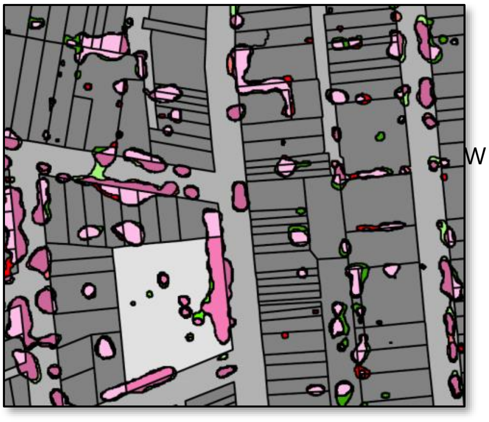
Tree growth visualisation

Growth of existing canopy can be visualised. Both Monash (VIC) and Mosman (NSW) showed canopy cover growth of 5% in a single year. This was empirically correlated to increased rainfall as the result of La Nina. This underscores the criticality of water and, hence, watering as part of a canopy retention and growth plan.

Accountability

Canopy can also be attributed and mapped to landholders with proportions and performance both being readily calculable.

With that, strategies can be developed with specific KPI’s set to those landholders, e.g.:



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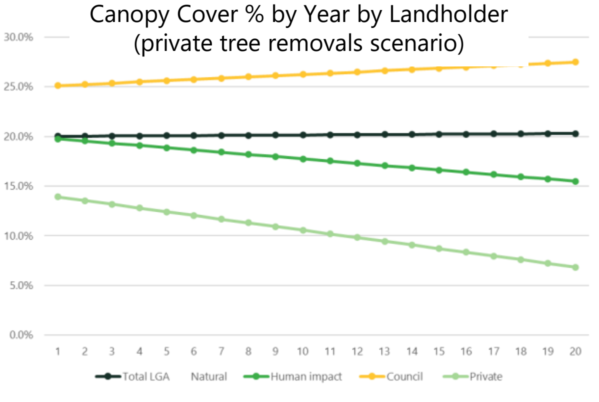
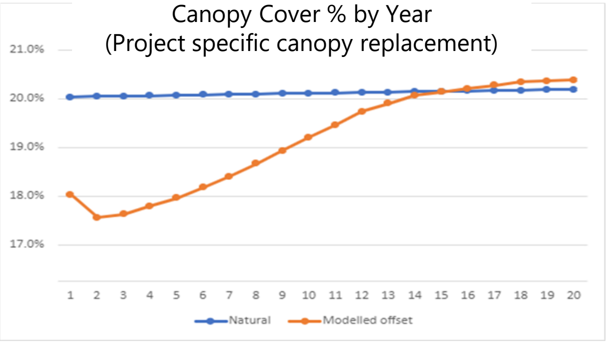




Further, KPI’s can be set around the impact of specific activity types:

Canopy loss

- Removal
- Pruning
- Natural decline (ULE, disease, climate)

Canopy gain

- Natural seeding
- Maturation (growth existing)
- Planting
- Promotion (watering, nutrients)
- Replacement (developer compensated)

Appendices

Data acquisition and AI application

Data acquisition

Two types of data were acquired to train the AI model to determine tree canopy cover:

1. Raw satellite imagery with 50 cm^2 ground resolution of Alexandrina was collected from the Pleiades project for 25/1/22 (Woodchester), 26/1/22 (Ashbourne, Goolwa, Middleton, Mount Compass, Port Elliot, 27/1/22 (Langhorne Creek), 4/2/22 (Clayton Bay) and 14/1/22 (Milang and Strathalbyn), Several dates were necessary to account for data availability and cloud cover.

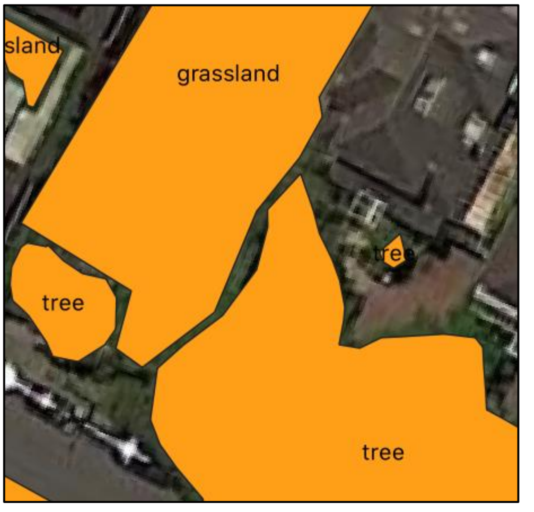
   More information about the Pleiades project can be found at: https://earth.esa.int/eogateway/missions/pleiades

   The data included multiple different frequency bands. The different bands provide different aspects of the imagery, some of which are invisible to the human eye such as near infra-red, but nonetheless provide vital information for the AI model in detecting vegetation and trees specifically.

Sample of an area showing Pleiades' Near-Infrared band (right side, in grayscale), next to Google Sat aerial imagery (left side, colour image).

2. Label annotations. These are the "ground truth" - markings on the imagery indicating the locations of trees, buildings, streets and other relevant objects. Additional labels were produced by LiveEO's team of data collection specialists, especially for the Alexandrina area.

AI training and classification



Example of area before and after labelling.

For this project, LiveEO designed and trained a Convolutional Neural Network (CNN) machine learning model. This is one of the most advanced AI architectures to solve computer vision tasks, commonly found in technologies such as autonomous vehicles and facial recognition. The CNN studies the combination of raw imagery and labels and learns which patterns in the raw imagery correspond to which labels. Having learned the right patterns, it can then accept raw imagery and produce its own labels - in this case indicating the tree coverage.

The CNN works by sliding filters (feature detectors) across the imagery, looking for certain patterns, based on which it produces a pixel-to-pixel classification of the imagery. During the training phase of the CNN, these filters are adjusted to correct errors in the classification output by comparing it to the ground truth annotations. This is how the CNN learns. It is a delicate, “little-by-little” type of process, and usually takes many iterations to complete and careful parameter tuning to achieve high quality of classification.

When the CNN has completed its learning iterations, it is ready to accept new, unseen imagery and produce accurate classifications, for example on imagery from a different year or spatial location.

Minimum Tree size for classification

The CNN requires a minimum of 4 pixels of 50 cm^2 to denote a “tree”. This means than the smallest canopy detectable, assuming a perfectly circular canopy with pixels 100% within the circumference, is 1.5 m^2 . As the pixels are unlikely to be 100% within the circumference, the practical minimum canopy area that will be classified as a tree is 2.2 m^2, assuming a reasonably circular canopy.

Data processing, validation and presentation

Data was loaded into various GIS and Mapping applications to verify coverage, overlap and spatial accuracy.

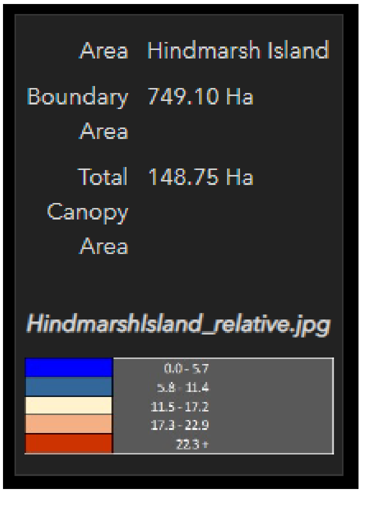
No AI model to date has provided accuracy at the level required for this quality of work without manual visual assessment and correction.

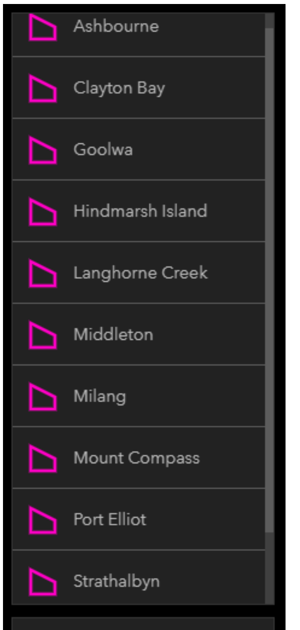
This is done by expert arborists and geo-spatial specialists overlaying data on recent high-resolution aerial imagery. Once adjustments are made, accuracy and coverage confirmed, layers are migrated into ESRI Spatial Databases for further processing.

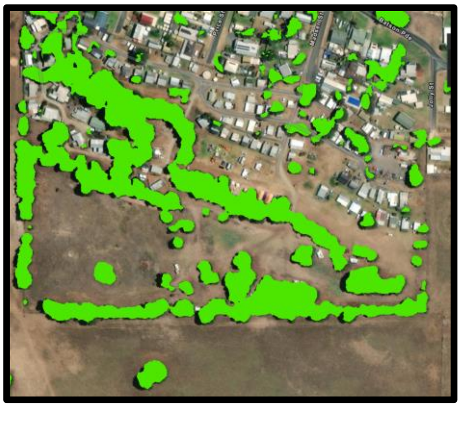
Data was then tuned to ensure performance and designed to accommodate any future additions. Visual adjustments are made to aid viewing, performance and useability.

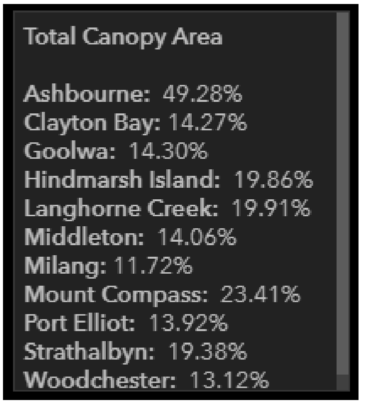
Calculations were applied to give relatable numbers, with dynamic widgets to provide interactive canopy on a per screen basis alongside a thermal image with relative radiant temperature shown such that visual correlation can be made.

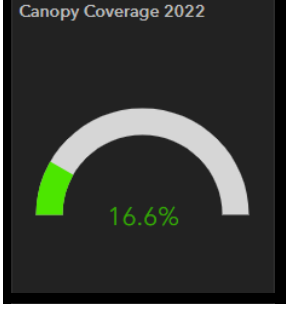
A link was set up to facilitate sharing with and use by Council staff and enable any further updates as required.











Accuracy

High resolution satellite imagery (50 cm^2) interpreted by AI to provide canopy data has only been used by Australian LGA's from 2021. Previously, the accepted methods for measuring canopy were i-Tree and Vegetation Indices. Both typically used low resolution satellite data.

i-Tree is a sampling technique where a human manually interprets an image and the results extrapolated. Errors in human interpretation have been shown to be around 10% (*[2]) and there is the significant complication of the uneven distribution of trees in urban areas.

NDVI (Normalized Difference Vegetation Index), and the more advanced vegetation indices that followed, all rely on a correlation between mathematically interpreted near infrared and other spectral data, and sampled, ground-truth data. It does not identify individual trees. This is the method-type used to generate previous state government data sets.

The accuracy of these methods can be summarized as being between +/- 10 to 20% (*).

AI interpreted satellite imagery (and aerial imagery) has the advantages of being able to both cover the entire area to be assessed and identify individual trees (or tree groups). AI models have to be trained, and the quality of training data significantly impacts a model's performance. We have found that models are improved by training based on the specific area being assessed. Experience puts the accuracy of reasonably trained AI models at + / - 5%. For Alexandrina, additional model training was undertaken, and the accuracy for the total result empirically estimated at + / - 3% at the 95% confidence level.

In the display of canopy comparing to visual imagery when being viewed on a GIS platform, two key factors must be remembered: 1. The date of the image is extremely unlikely to match the date of the data so it is possible that a tree has been removed or grown in size, and 2. Image alignment will be imperfect, typically in the order of a meter or two, due to orthorectification, geospatial positioning and, potentially, wind.

Due to the resolution of the satellite imagery, isolated trees with canopy less than 2m in diameter will generally not be detected. Particularly for small trees at or around the detection limit, small variances in the satellite imagery can also tip the output of the model from detecting a small tree to missing it, making the detection of these small trees less reliable.

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