Department of Spatial Sciences

Urban Forest Canopy Coverage and its Effect on Heat Islands in the City of Melville

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ABSTRACT

The City of Melville has been investigating the effects of urban heat islands in their jurisdiction. This project will use thermal imagery and point cloud data from an airborne laser scanner to acquire data and investigate relationships between land and canopy coverage of the City of Melville, and the surface temperature over the same area. By the end of this report, the findings will be summarised and any recommendations on ways to mitigate the urban heat island effect in the City of Melville will be suggested.

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1. INTRODUCTION

According to a survey conducted by the Pew Research Centre, the majorities in 23 out of 25 countries agree that protecting the environment and addressing global warming should be a higher priority than the growth of the economy (Pew Research Center, 2009). These statistics suggest that global warming is an important issue globally and that many believe steps need to be taken to combat its effects. Cities and their populations are the subjects most at risk form the impacts of climate change (Ivanivic, Munshey, & Bosetti, 2015). The cities or urban areas (classified as centres with a population greater than 100,000 people) are where the majority of Australian's live (ABS, 2006). Therefore combatting global warming is especially important in Australia. The reason this phenomenon has a greater impact on residents of urban areas compared to those in non-urban areas, is due to the Urban Heat Island (Ivanivic, Munshey, & Bosetti, 2015).

An urban heat island refers to conditions occurring in built up areas of heightened air and surface temperatures compared to the surrounding or nearby rural or less built up areas. This is often most noticeable during the night with the built up areas experiencing higher minimum temperatures. These regions have larger areas of brick, concrete, asphalt etc. which are able to absorb more energy during the day than rural regions with more vegetation. The result of this, is these materials radiate more heat energy at night time, resulting in the temperature dropping as less than it would otherwise had the land not been developed. The lack of shade due to absence of vegetation coverage further adds to this effect, as the built up areas have greater exposure to solar radiation (William D. Solecki, 2005).

2. BACKGROUND

2.1 Aerial Laser Scanning (LiDAR)

LiDAR (Light Detection and Ranging) is a method of remote sensing that measures ranges to the Earth through the use of light in the form of laser pulses (National Ocean Service, 2013). As the system emits laser pulses over the project area, the outgoing pulses are then reflected back from the ground and surface features and recaptured by the sensor. The distance from sensor to surface object is then calculated from the time delay between the transmission and detection of each laser pulse (Photomapping, 2015). Combined with additional data recorded from the airborne system, precise three dimensional information about the shape and characteristics of the subject land can be collected and additionally modelled (National Ocean Service, 2013).

LiDAR is an established means of dense and accurate data collection over various landscapes which can also include shallow water bodies and project sites.

2.2 Remote Sensing

Remote sensing is a method of obtaining spectral information of an area of land from a large distance. Aerial remote sensing uses photographic cameras or multi-spectral scanners attached to airborne platforms such as balloons and aircraft, in order to obtain photographs of a desired area of the Earth's terrain (Dwivedi, 2001). A remote sensor is usually mounted to these vehicles, and retrieves data from the reflected energy of the land. These sensors can either be passive (do not output any stimuli, only detect naturally occurring energy), or active (output an internal stimuli such and a laser and measures its reflection) (National Ocean Service - U.S. Department of Commerce, 2017).

Remote sensing collects information in a series of bands. These bands are classified by certain wavelength intervals and correspond to regions on the multispectral array. The bands can extend beyond the visual spectrum into infrared and even further to thermal infrared.

All objects with a temperature greater than absolute zero (0K or -273℃) emit thermal infrared energy. This therefore means that all objects on Earth emit thermal infrared radiation. The human eye cannot detect this radiation as it has a wavelength of 3.0µm - 14 µm. This wavelength range is above the human eye visible spectrum which is 400nm – 700nm (Jenson, 2007). This data, since 2013, has been collected using the

Landsat 8 satellite. This satellite is equipped with a Thermal InfraRed Sensor (TIRS). It is the first Landsat satellite to use Quantum Well Infrared Photodetector arrays (QWIPs) to detect infrared radiation. This sensor is able to detect long wavelengths of light emitted by the Earth of which the intensity is dependent on the surface temperature (NASA, 2017).

2.3 Objectives

The objectives of this project are to investigate how the land usage and vegetation distribution in the City of Melville affect the radiant heat of the corresponding areas. This investigation will be split into three objectives;

1. Using aerial laser scanning (LiDAR) data to obtain information about the land coverage, most specifically the vegetation canopy throughout this city as well as the sealed areas and buildings.
2. Using thermal remote sensing data provided from the City of Melville in order to deduce the radiant ground temperature throughout the City of Melville.
3. Correlate and establish relationships between the two sets of data to investigate the contributing factors to the urban heat island effect.

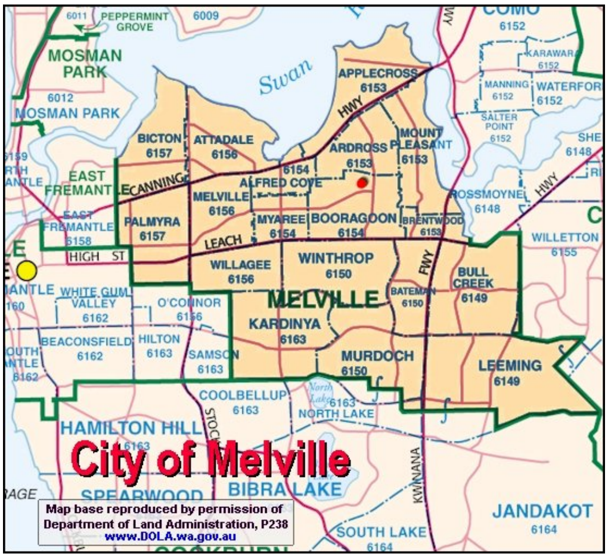

Figure 1: City of Melville Boundary (City of Melville, 2008)

The urban heat island effect is likely to be correlated to a number of factors such as; reduced vegetation in urban areas; materials used in urban areas having higher solar reflectance, higher thermal emissivity and a greater heat capacity; and urban geometry, i.e. the spacing between buildings, solar reflectance off the walls of buildings (also related to colour and/or material of walls) and air flow permeability (U.S. EPA, 2012).

3 METHODOLOGY

3.1 ALS

The objective of the project is to classify the tree canopy in the City of Melville and to see what effect different classifications have on the heat of the corresponding areas. In order to do this, we need a method which can record the height of all points in our study area. To deliver this information we have used aerial laser scan (ALS) data retrieved from a Riegl VZ-1000 scanner.

This scanner recorded the data and has provided the output information in the form of .LAZ files. This file format is able to be processed using the open source program, LAStools. LAStools provides an interface that reads the .laz files and outputs the data in visual form.

Riegl VZ-1000 - Specification

General	VZ-1000
Instrument Type	High-accuracy, high-precision ranging based on echo digitization and online waveform processing
Data Storage	32Gb onboard flash memory
User Interface	Onboard colour display and keypad or external PC
System Performance	
Accuracy	8mm
Precision	5mm
Laser Scanning System	
Type	Echo digitisation and waveform processing **+ full waveform recording**
Laser Class	1
Range	1.4km @ 80%; 520m @ 10% albedo
Scan Rate	Up to 122,000 points/sec
Spot Size	7mm at exit + 0.3mrad divergence
Field of View	360° (horizontal)
	100° (vertical)
Electrical	
Power Supply	11-32V DC
Power Consumption	82W typ., 90W max.
Battery Type	External 18Ah NiMH supplied, other 12V source can be used
Duration	around 5 hours of scanning
Environmental	
Operating temp.	0° to +40° C (lower for short periods)
Storage temp.	-10° to + 50° C
IP Rating	IP64
Altitude Limit	Specified to a maximum operating altitude of 2000m
Physical	
Dimensions	190 x 195 x 370mm
Weight	9.8kg (scanner), 29.8kg (all accessories and case)

Figure 2: Riegl VZ-1000 Specifications (U.K. NERC, 2015)

One function of this program which satisfies the needs for this jobs is the LASclassify function. Here the user is able to read in the desired .laz files recorded from the scanner and sort the point cloud data in various height intervals such as surface, low ground, low vegetation, medium vegetation, high vegetation and buildings. The user is able to have all these classifications shown, or only certain ones if that is what is required. Figure 3 below shows a tile of an area in the City of Melville that has all 5 layers visible. Layer 2 (Ground) is shown as brown, layer 3, 4 and 5 (low, medium and high vegetation) are shown as green, and layer 6 (buildings) is shown as orange.

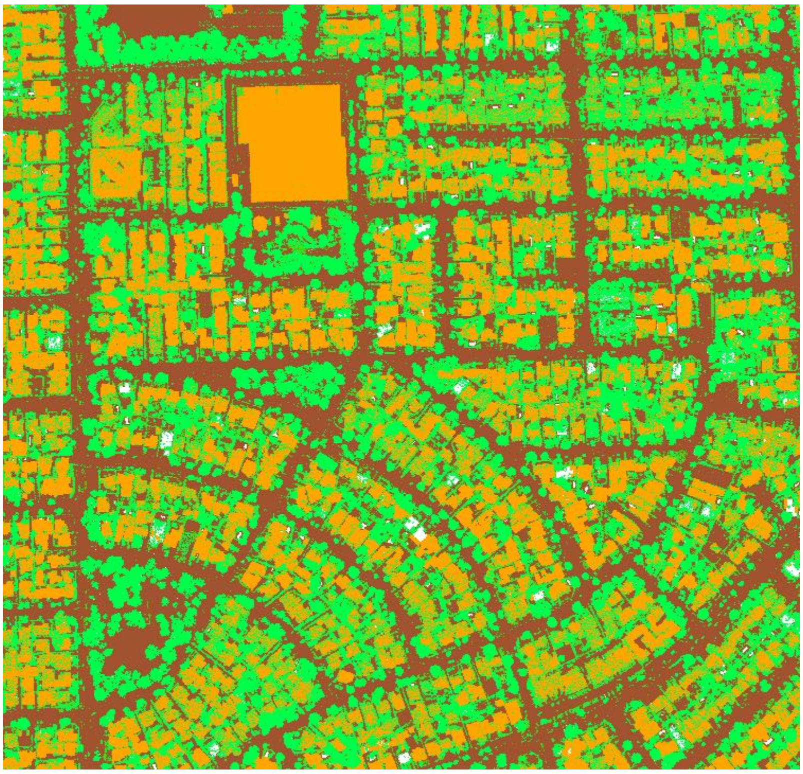

Figure 3: Height classified image from LAStools of an area in City of Melville

To analyse each layer in terms of area, each class (layer) is to be selected individually and then output as a shape file. The classes are sorted as follows;

- Class 2: Ground
- Class 3: Low Vegetation
- Class 4: Medium Vegetation
- Class 5: High Vegetation
- Class 6: Buildings

The shape file is a vector format file which can be used in ArcMap to display the areas in terms of polygons. This will be useful later when conducting comparisons with the thermal imagery.

LAStool analyses the LiDAR data in square sections called tiles. However, the size of the tiles in LAStools is quite small, and it is required that an extensive and diverse area throughout the City of Melville is analysed. So in order to do this, all the separate tiles making up the entire City of Melville must be all processed together and merged to create shapefiles of each class covering the entire area of the city. One problem that occurs when all tile are analysed as one group is that the precision of the shapefiles are reduced, because what is happening is the entire region is essentially compacted into the space of a single tile. To combat this, there is a parameter called "Concavity" that can be altered. Concavity essentially refers to the precision of the geometric shapes formed around the point cloud from the LiDAR data, so if a high concavity is entered, then the shapes formed will be larger than if a low concavity is entered, which will make the shapes much tighter and more precisely representing the coverage of each region. Figure 4 shows a comparison between a high concavity and a low concavity for a section of the medium vegetation layer.

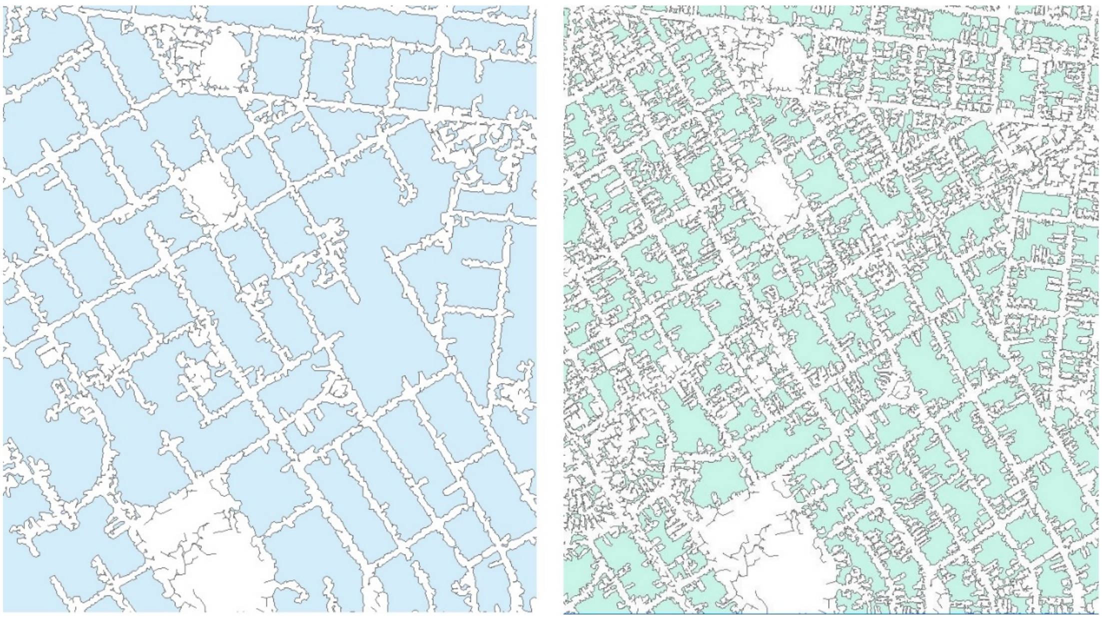

Figure 4: Shapefiles of same area; left: high concavity; right: low concavity

As Figure 4 shows, it is clear that having a lower concavity is going to provide a more detailed description of the type of coverage in the area, therefore this project is using the lowest concavity possible so that the results are as accurate and precise as possible.

3. 2 Thermal Imagery

The City of Melville has provided a thermal image of its jurisdiction using a FLIR A615 camera. The thermal image provided is in a .tif data format. This is a type of raster format that can be opened in ArcMap. ArcMap displays the image initially as a greyscale graduated heat ramp image as see in Figure 5 below.

Figure 5: Thermal Image as displayed in ArcMap

Also provided in the data from the City of Melville was a shapefile of the city's boundary. This is used to clip around the city's perimeter, getting rid of all the black area of no data and leaving only the study area.

Now it is possible to alter the colour ramp so that the image now shows a better representation of the temperatures of the region. Figure 6 below shows the study area with the lower temperatures in green and increasing through yellow until the highest temperatures are displayed in red.

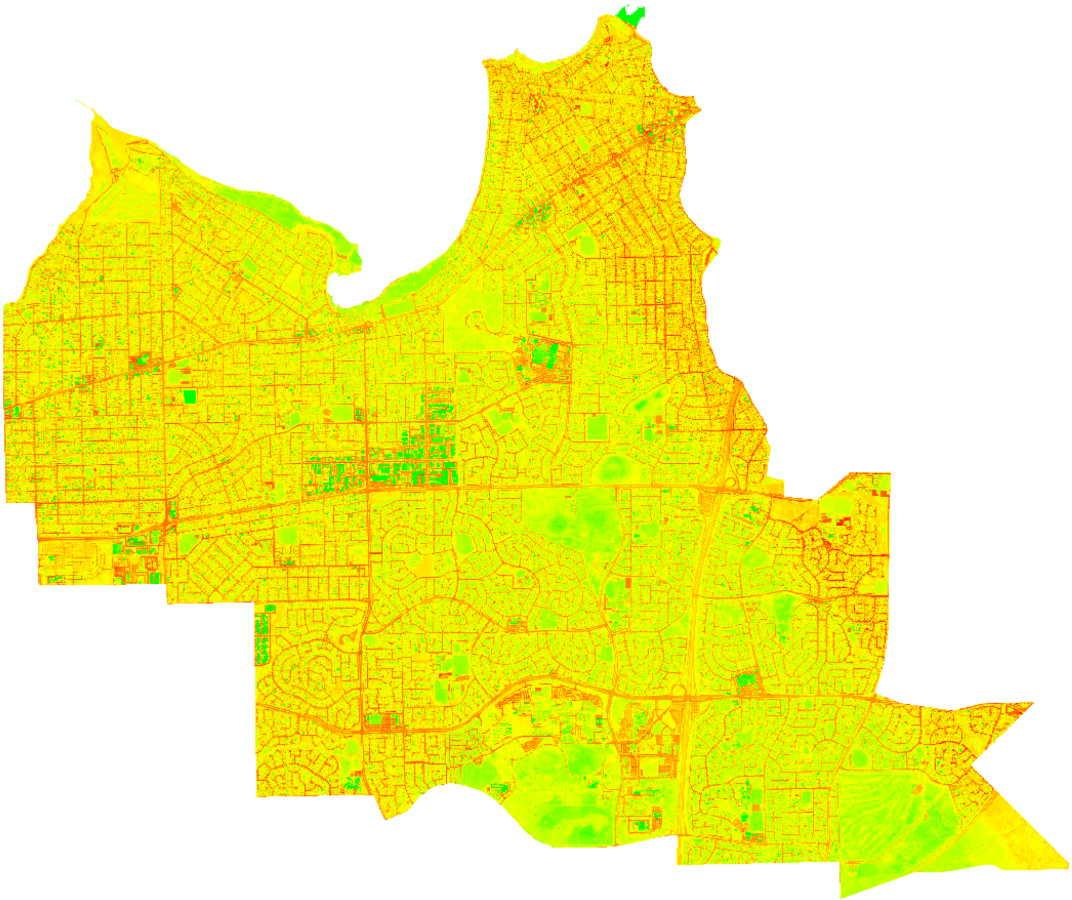

Figure 6: Clipped thermal image with logical colour ramp

This however is only really useful as a visual aid at this point. In order to work with this in a way which presents meaningful data that can be used for comparisons with the laser scan data, further steps are needed.

This thermal image was taken between the hours of 9pm and 12am, therefore without and solar radiation from the sun. This means that the range of temperature over the area is only about 6°C. Therefore the simplest way to gather data to use in the comparison with the laser scan data, is to separate the thermal image into three categories; low temperatures, medium temperatures and high temperatures.

ArcMap has a function named "reclassify" (shown in Figure 7) which allows this to be done. The process simply involves assigning the existing temperature values to new values, i.e. temperatures less than 12°C = 1, temperatures between 12°C and 14°C = 2, temperatures greater than 14°C = 3.

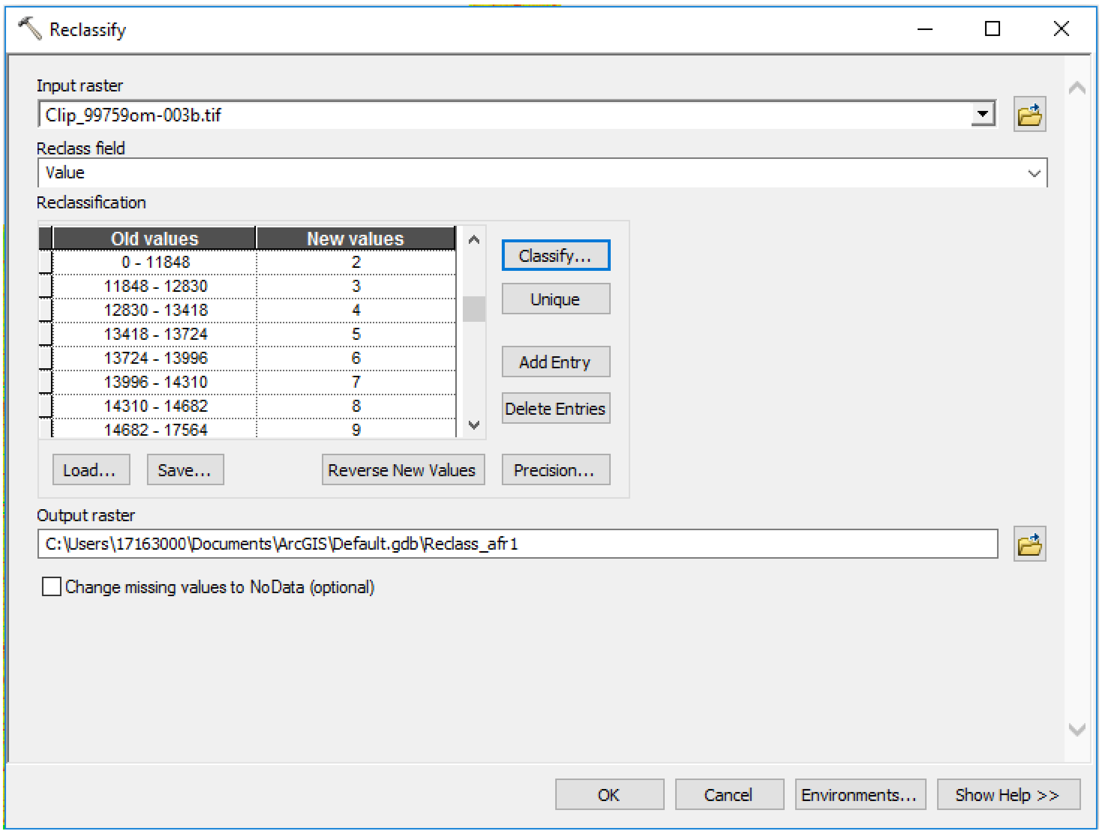

Figure 7: Reclassify Function

This process produces a thermal image that is split up into three distinct categories according to the temperature levels. The most logical method to display this is by assigning the low temperature regions with a cool colour such as a shade of green or blue, assigning the medium temperatures with a warmer colour such as a shade of yellow or orange, and finally assigning the high temperatures with a shade of red (see Figure 8). In this form, it is already possible to gain some qualitative results as to what may cause some areas to be cooler and some to be hotter. This can be done by using any satellite imagery with a high enough resolution such as Google Maps (Google, 2017) and investigating any patterns that may emerge relating to areas with distinct temperature differences and what objects or feature e.g. trees, roads, roofing, pools, colours etc. they correspond with.

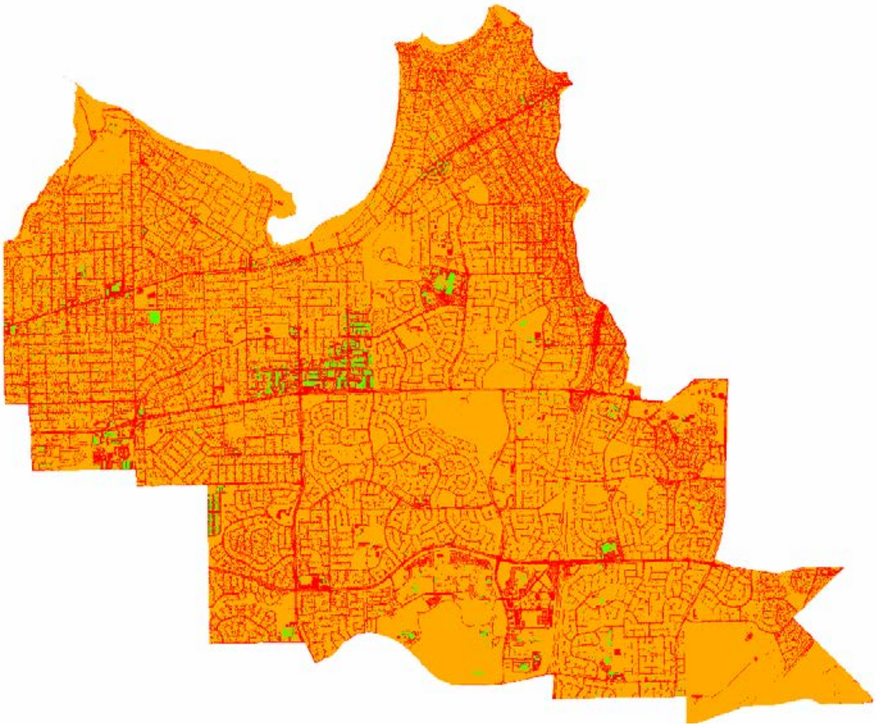

Figure 8: Raster heat map of the City of Melville

Furthermore, after using this above date shown in Figure 8, these three heat intervals can be converted into separate layer by converting them from raster format, to individual shapefiles using the “Raster to Polygon” tool in ArcMap (see Figure 9). The reason for doing this is to make it possible for the area that each heat interval is covering to be calculated, because while raster format is based on pixels, polygon shapefiles are based on geometric shapes that have an area, thus allowing the area of each temperature bracket to be determined.

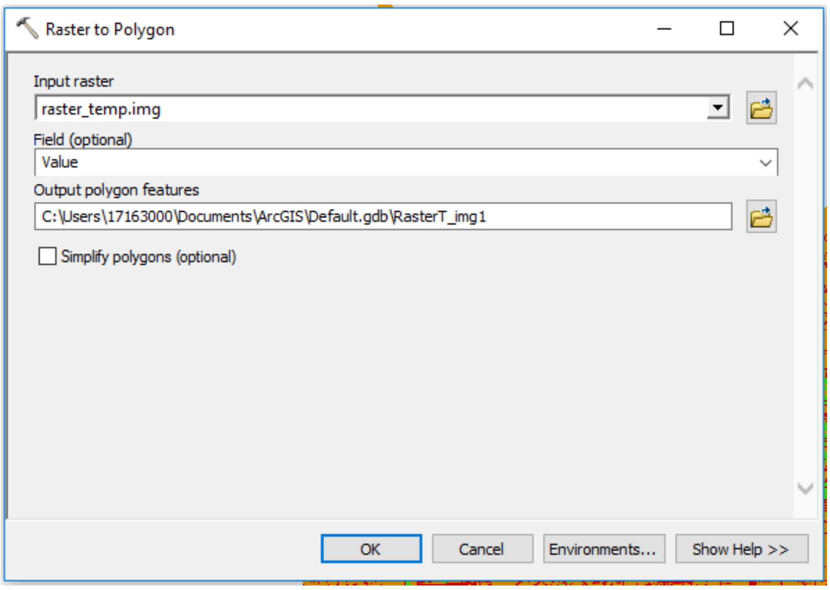

Figure 9: Raster to Polygon tool

Once this process is complete, a new polygon shapefile layer will be produced containing the three temperature intervals now presented as geometric shapes instead of an array of pixels.

3. 3 Comparison

Now that shapefiles for both the temperature ranges and the LiDAR scanning classes of the City of Melville have been produced, comparisons between the two sets of data can be investigated.

Instead of analysing the area for the entire city, five sub-regions have been selected as study zones in order to compare different parts of the city and possibly see what regions are managing to reduce the heat island effect. The sub-regions chosen are done in a manner as to cover a good even selection of the city, while also including special use areas such as the commercial/industrial precinct of Myaree and the higher density areas around Applecross. Figure 10 shows the selected study areas within the city of Melville.

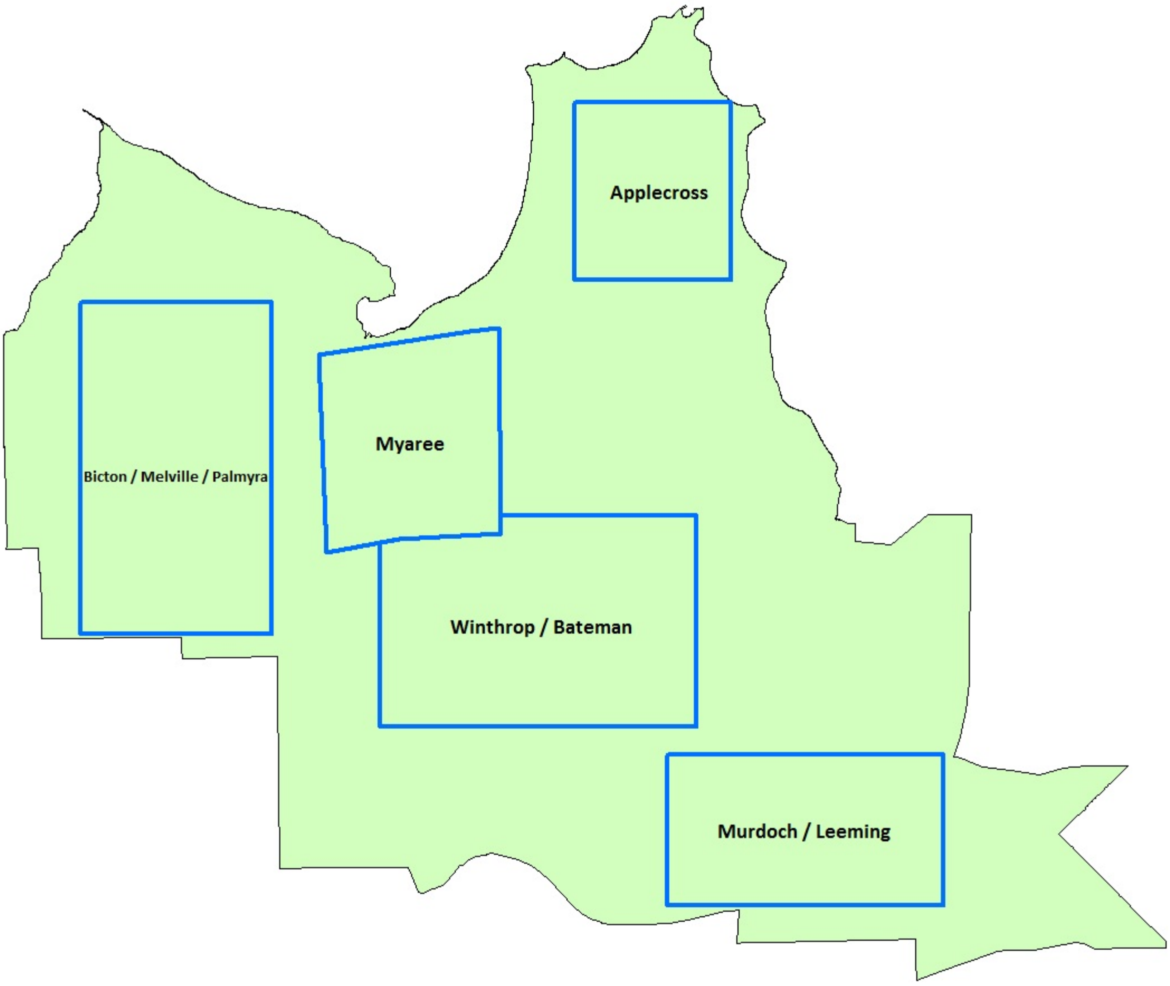

Figure 10: Study Regions

Finally, ArcMap can display a table of all the regions and the area within each region covered by each different shapefile layer. This process is conducted once for the LiDAR data shapefile layers, and once for the thermal imagery shapefile layers. These tables can then be exported to excel and further refined in order to display total area of each region, the area each separate layer covers in each region and therefore the percentages of coverage over each study area.

4 RESULTS / EVALUATION

4.1 Aerial Laser Scanning

The resultant processing of the LiDAR scanning in LAStools produces the five classes of layering in a shapefile format. The ground layer will not be analysed because it will not have anything to relate to due to it being a base layer which covers the entire area. Therefore, the layers to be analysed will be the low vegetation, medium vegetation, high vegetation and the building layer.

Figure 11, Figure 12, Figure 13 and Figure 14 below shows the resultant shapefile layers produced from processing the point cloud data in LAStools.

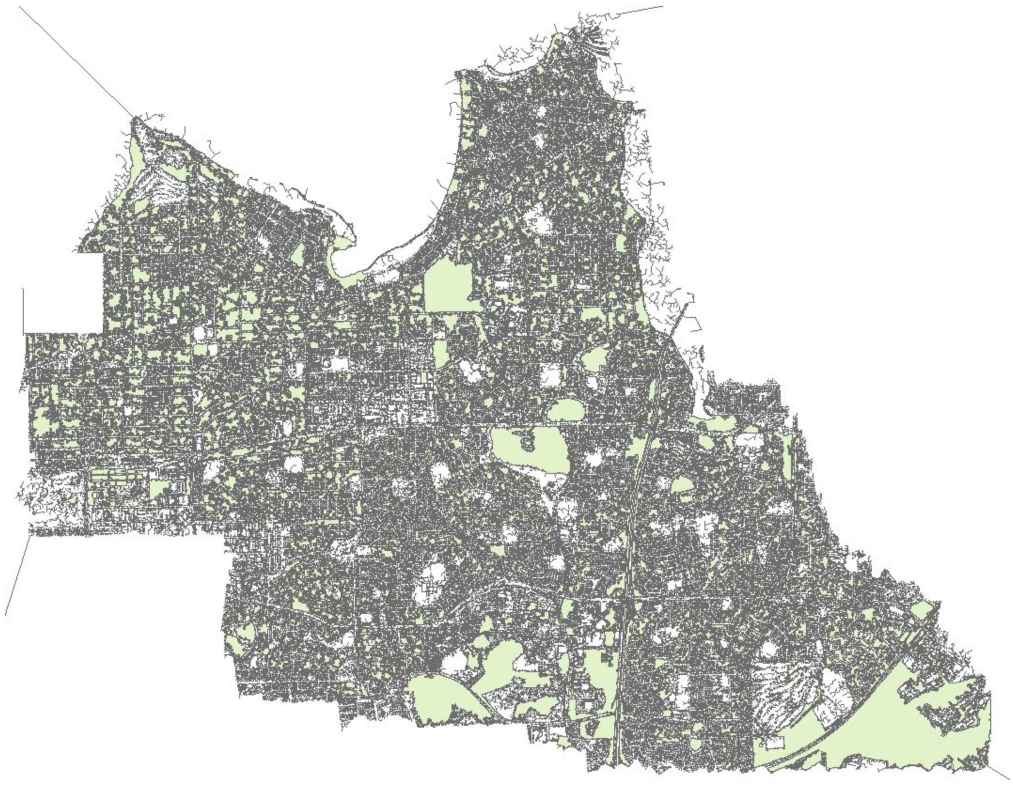

Figure 11: Low vegetation shapefile of the City of Melville area

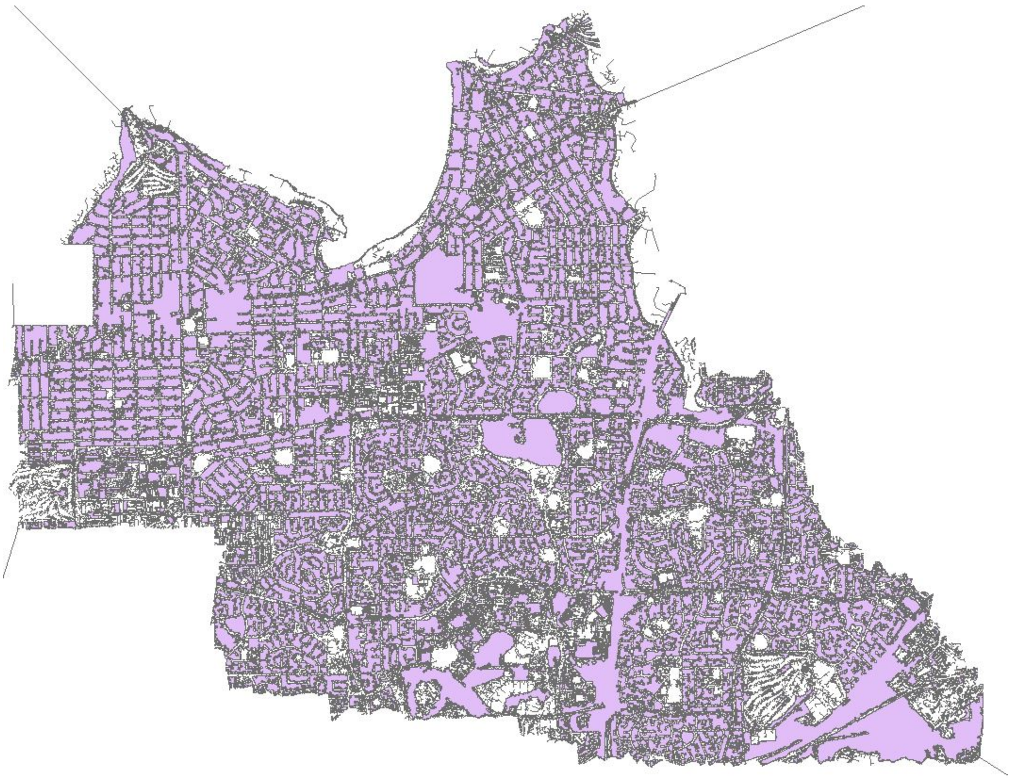

Figure 12: Medium vegetation shapefile of the City of Melville area

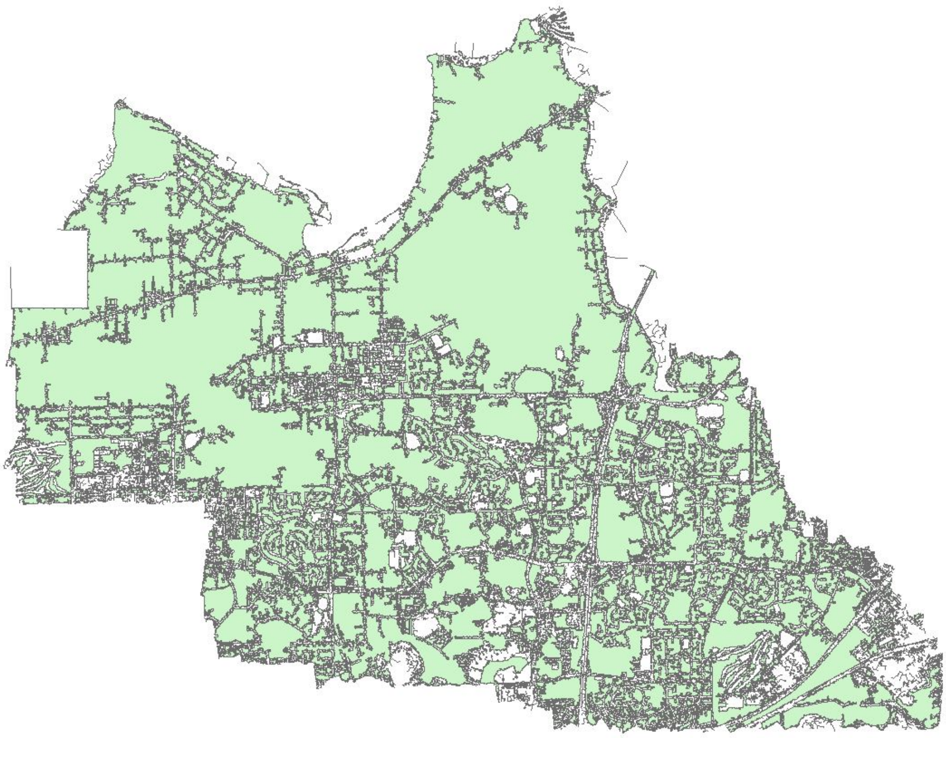

Figure 13: High vegetation shapefile of the City of Melville area

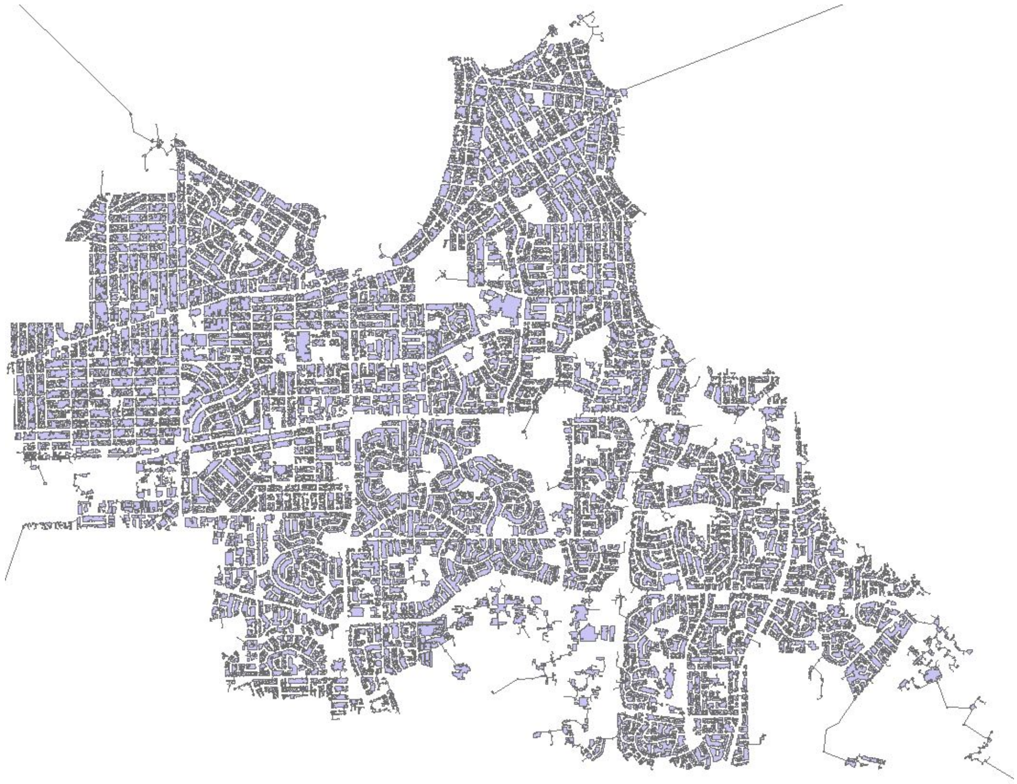

Figure 14: Building layer shapefile of the City of Melville area

Some of the features evident from visually analysing these shapefiles is that the low vegetation is fairly evenly distributed throughout the city's area, with large patches occurring in parkland regions. This is basically classifying the grassed regions and suburban house gardens in the front and backyards. A similar coverage occurs with the medium vegetation, however because they are taller, the canopy covers a greater area than the low vegetation therefore we see the shapefiles containing in general, larger shapes. The high vegetation shapefile shows some interesting results. It is visibly clear to see the regions that have more treelines streets and this somewhat corresponds to the age of the suburbs. The suburbs in the northern half of the city were generally established earlier than those in the south (City of Melville, 2017), and it is evident that the northern half has a significant amount of high canopy coverage compared to the southern suburbs. This suggests that the planning strategies may have changed overtime with more land being cleared for the newer areas compared with the older areas.

The analysis of the area coverage for each class in their respective study areas was processed using ArcMap. These area statistics are shown below in Table 1.

Study Area	Buildings (m2)	High Vegetation (m2)	Medium Vegetation (m2)	Low Vegetation (m2)
Bicton / Melville / Palmyra	2381527.31	4668745.46	3668677.46	2306896.87
Applecross	1047050.21	2228638.53	1440969.88	634905.44
Winthrop / Bateman	1871848.81	3853062.35	3109959.03	1834360.44
Murdoch / Leeming	909771.51	2165380.53	1895302.16	1177454.62
Myaree	1206954.90	2038323.05	1739803.35	891627.82

Table 1: Area Statistics for LiDAR scan data of the City of Melville

This data alone does not tell us a lot because each study area is of a different size. So a better was of displaying this data is as a percentage of the total area of each study area. This is displayed below in Table 2.

Study Area	Buildings (%)	High Vegetation (%)	Medium Vegetation (%)	Low Vegetation (%)
Bicton / Melville / Palmyra	41.87	82.07	64.49	40.55
Applecross	42.06	89.53	57.89	25.50
Winthrop / Bateman	32.49	66.87	53.97	31.83
Murdoch / Leeming	24.31	57.86	50.64	31.46
Myaree	37.90	64.00	54.63	28.00

Table 2: Percentage of land coverage type in each study area

Displaying this data in a graph gives a better visual comparison between study areas and their land coverages as seen below in Figure 15.

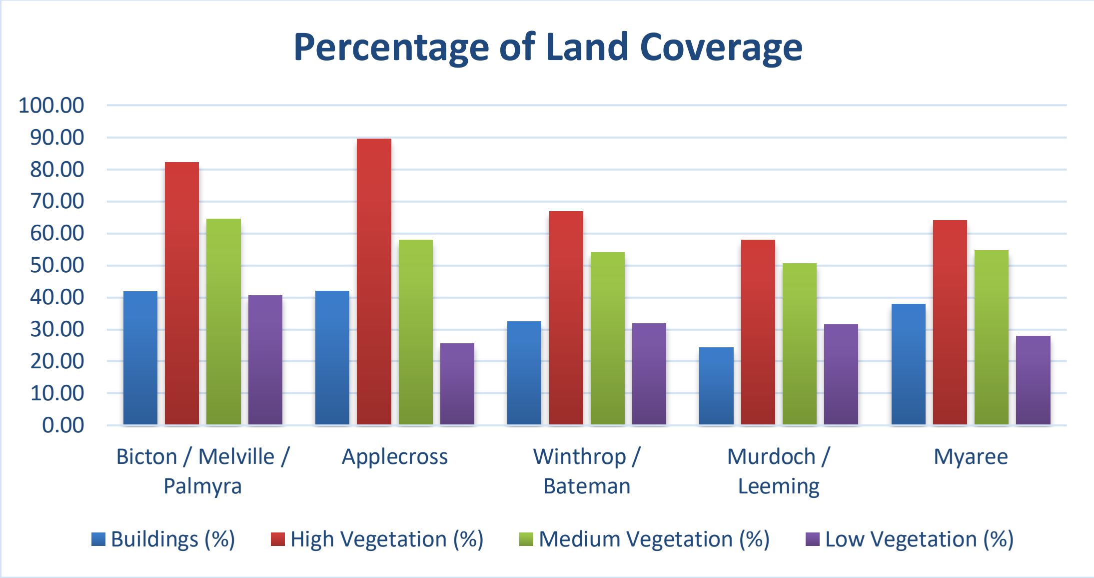

Figure 15: Graph showing percentage of land coverage type in each study area

This graph shows that indeed the Applecross study area has the greatest proportion of high vegetation coverage of the study areas at almost 90%. Conversely, the Murdoch/Leeming area which was developed in the 1980s and is one of the most recently developed regions in the City of Melville (City of Melville, 2017), has the lowest proportion of high vegetation coverage at below 60%.

The variations in low and medium vegetation coverage are quite small between the study regions so there isn't a lot to take from those statistics. The building coverage percentages, again don't have a lot of variation, however it does show that the Winthrop/Bateman and the Murdoch/Leeming areas, which are the two most recently developed areas in the city (City of Melville, 2017), have the lowest percentage of building coverage. This seems to highlight the development trends of the time being of lower density.

4.2 Thermal Imagery

The processing of the thermal imagery produces a shape file classified into three layers consisting of low temperatures (less than 12°C), medium temperatures (between 12 and 14°C) and high temperatures (higher than 14°C). Figure 16 shows an image of this temperature classification shapefile. (*note that the green low temperature spots have been given a thicker boarder to allow these areas to stand out and become more easily visible.)

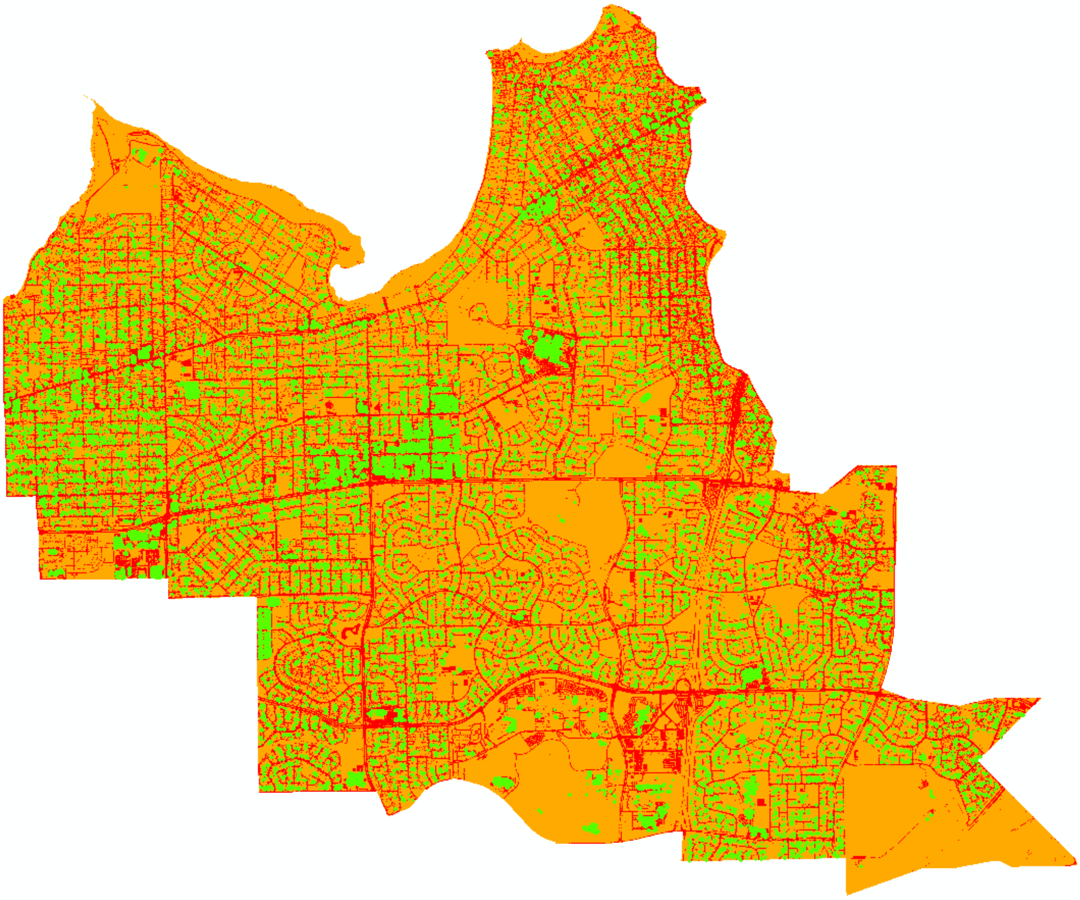

Figure 16: Shapefile of temperature ranges in the City of Melville

In the same way that the land coverage table was formed in 4.1, ArcMap is able to form table of the areas each heat interval covers in each study area. This data is shown below in Table 3.

Study Area	Low Temperature (m^2)	Moderate Temperature (m^2)	High Temperature (m^2)
Bicton / Melville / Palmyra	139940.11	3980045.18	1568534.43
Applecross	34900.34	1632824.42	821639.45
Winthrop / Bateman	27498.47	4747496.44	987150.82
Murdoch / Leeming	42998.14	2939919.21	759529.71
Myaree	223631.18	2081583.95	879551.99

Table 3: Area coverage of each heat interval for the City of Melville study areas

To make these figures more meaningful in terms of this project, it is better to calculate these statistics as a percentage of total area in each study area as was also done in 4.1. Table x below shows this data in percentage form.

Study Area	Low Temperature	Moderate Temperature	High Temperature
Bicton / Melville / Palmyra	2.46	69.97	27.57
Applecross	1.40	65.59	33.01
Winthrop / Bateman	0.48	82.39	17.13
Murdoch / Leeming	1.15	78.56	20.29
Myaree	7.02	65.36	27.62

Table 4: Percentage coverage of each heat interval in the City of Melville study areas

Displaying the data in Table 4 as a graph gives a better visual description of the data. Figure x below shows this data in the form of a graph.

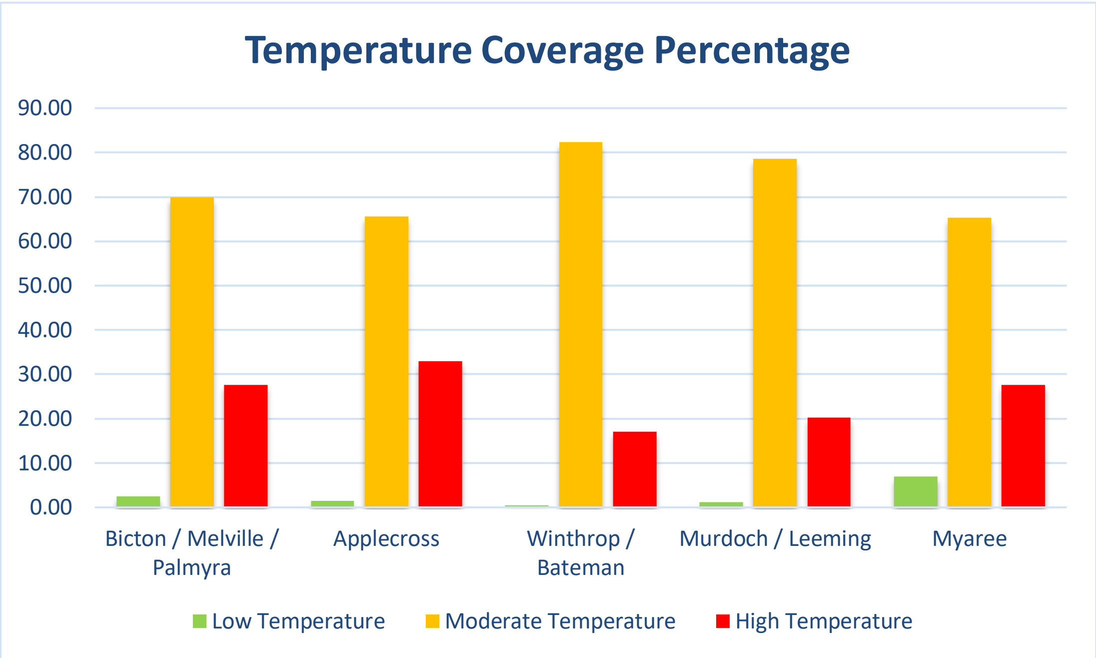

Figure 17: Graph of temperature interval coverage percentage in each study area

4. 3 Comparison

4.3.1 Qualitative Comparison (Thermal Imagery)

The thermal imagery data, when visually represented as a heat map with the low, medium and high temperatures clearly and discretely displayed can be used to visually compare with a satellite image (given its resolution is sufficiently high). Below shows a rectangular area containing the Myaree commercial precinct as well as some surrounding suburban and parkland areas. Figure 18 shows this area from a satellite image from Google Maps (Google, 2017), and Figure 19 shows the same area as a heat map.

Figure 18: Satellite view of Myaree (Google, 2017)

Figure 19: Heat map of Myaree area

What is interesting about these two images is that the commercial precinct, which has a distinct lack of vegetation, is actually quite cool, having a large area corresponding to the "low temperature" bracket. Outside the industrial area, there are a few scatterings of green "cool spots" around the area. When inspected closely, there is in fact quite a strong correlation between the cool green regions on the heat map, and the areas of white or light coloured roofing.

This affect is due to white or lighter colours having a lower capacity to absorb heat than darker colours (Hes, 2012). The thermal image used in this project was taken between 9pm and 12am, thus the sun had set before the images were taken and therefore no solar radiation was being radiated towards the Earth. This means that the project is measuring heat retention. So the reason these white and lighter coloured surfaces are showing up as cooler areas on the heat map, is because they were not able to absorb as much thermal radiation as the darker coloured areas, which in turn means that they do not have as much thermal energy that was absorbed during the day to emit back out as darker objects, and hence they are at a lower temperature at the time of the data collection (Hes, 2012).

Another qualitative analysis that can be carried out is looking at all the vegetation shapefiles overlapped on top of the heat map. This is shown below in Figure 20.

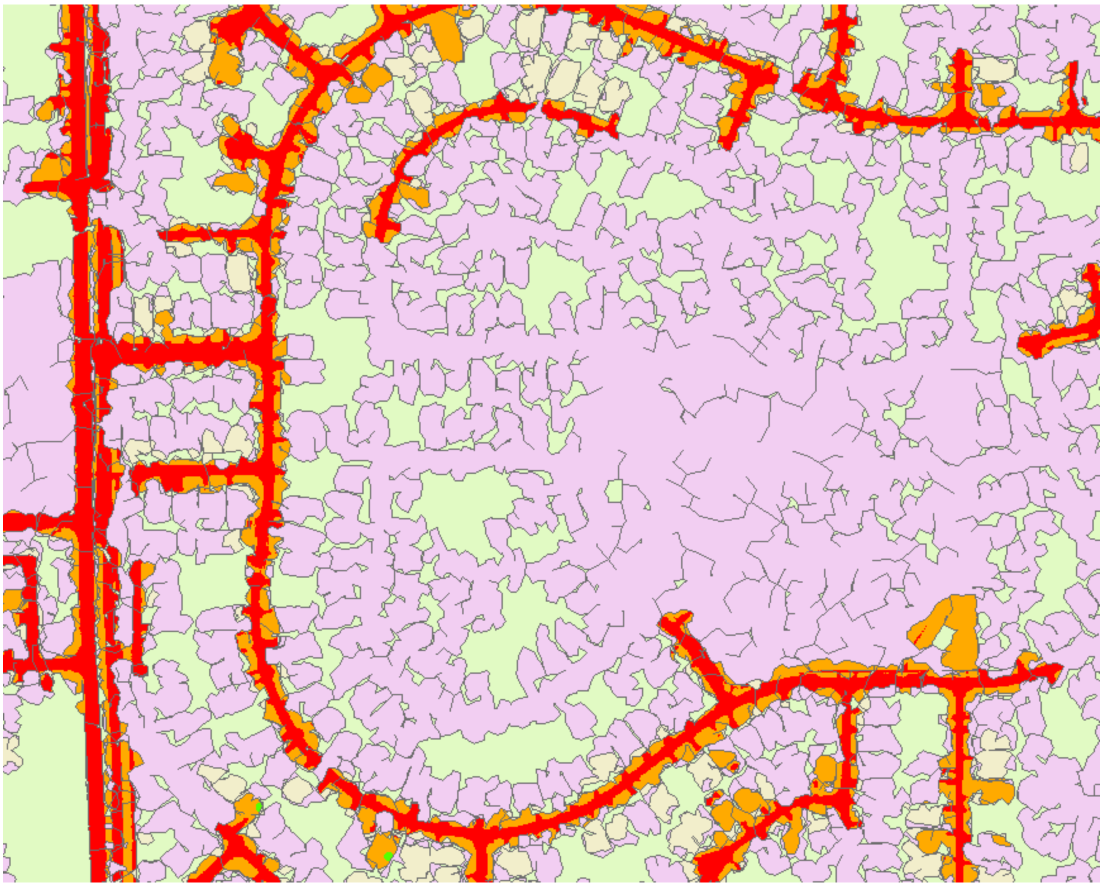

Figure 20: All vegetation layers overlapped over an area of the heatmap

As is evident in Figure 20, apart from a small amount of orange which represents medium heat, the only layer left visible on the heatmap is the red “high temperature” areas which highly correlate with the black asphalt road surfaces. This strongly suggests that the vegetation, regardless of height, has an effect on the surface temperature. This is most likely from shade (William D. Solecki, 2005), but may also be due to the vegetation not absorbing as much heat throughout the day as the asphalt does (Hes, 2012).

4.3.2 Relationship between Land Coverage and Temperature

4.3.2.1 Low Vegetation

	% Coverage
Bicton / Melville / Palmyra	40.55
Low Temp	2.46
Medium Temp	69.97
High Temp	27.57

	% Coverage
Winthrop / Bateman	32.49
Low Temp	0.48
Medium Temp	82.39
High Temp	17.13

	% Coverage
Applecross	42.06
Low Temp	1.4
Medium Temp	65.59
High Temp	33.01

	% Coverage
Murdoch / Leeming	24.31
Low Temp	1.15
Medium Temp	78.56
High Temp	20.29

	% Coverage
Myaree	37.9
Low Temp	7.02
Medium Temp	65.36
High Temp	27.62

As determined in the qualitative results 3.5.1, Myaree is going to be an outlier due to the fact that is has a large area of commercial land where there is very little vegetation. There is not a lot to see from the inspection of results of the low vegetation other than a possible link between a lower proportion of low vegetation coverage correlating with a larger area of medium temperatures. The Bicton/Melville/Palmyra region and the Applecross region have the two largest proportions of low vegetation coverage, and the area taken up by medium temperatures in 69.97% and 65.59% respectively. On the other end of the scale we have the Winthrop/Bateman region and the Murdoch/Leeming Regoin with the lowest proportions of low vegetation coverage, and the each have notably higher areas of medium temperatures with 82.39% and 78.56% respectively.

4.3.2.2 Medium Vegetation

Bicton / Melville / Palmyra	% Coverage
	64.49
Low Temp	2.46
Medium Temp	69.97
High Temp	27.57

Winthrop / Bateman	% Coverage
	53.97
Low Temp	0.48
Medium Temp	82.39
High Temp	17.13

Applecross	% Coverage
	57.89
Low Temp	1.4
Medium Temp	65.59
High Temp	33.01

Murdoch / Leeming	% Coverage
	50.64
Low Temp	1.15
Medium Temp	78.56
High Temp	20.29

Myaree	% Coverage
	54.63
Low Temp	7.02
Medium Temp	65.36
High Temp	27.62

Again, the Myaree study area appears to be an outlier with these results for medium vegertation coverage as explained in 3.5.2.1.

There seems to be a small correlation between higher percentage of medium vegetation coverage and high temperature coverage. The study areas of Bicton/Melville/Palmyra and Applecross have the two highest proportions of medium vegetation coverage and they also have the two highest areas (not including Myaree) of high temperature coverage. However, this may just be coincidental as Applecross has the largest percentage of high temperature but is second to Bicton/Melville/Palmyra in terms of medium vegetation coverage but over 6%.

4.3.2.3 High Vegetation

Bicton / Melville / Palmyra	% Coverage 82.07
Low Temp	2.46
Medium Temp	69.97
High Temp	27.57

Winthrop / Bateman	% Coverage 66.87
Low Temp	0.48
Medium Temp	82.39
High Temp	17.13

Applecross	% Coverage 89.53
Low Temp	1.4
Medium Temp	65.59
High Temp	33.01

Murdoch / Leeming	% Coverage 57.86
Low Temp	1.15
Medium Temp	78.56
High Temp	20.29

Myaree	% Coverage 64
Low Temp	7.02
Medium Temp	65.36
High Temp	27.62

With Myaree again seeming to be outlier, we have Bicton/Melville/Palmyra and Applecross having the highest proportion of high vegetation coverage and by quite a fair margin. These areas also have the most area covered with low temperature zones (not including Myaree). However, this again is not a very strong correlation and may only be a coincidence because Applecross is ranked first for percentage of high vegetation coverage by about 7.5%, but it ranks behind Bicton/Melville/Palmyra for low temperature coverage by 1%, which is significant because the low temperature coverages are very low in all study areas except for Melville.

4.3.2.4 Buildings

	% Coverage
Bicton / Melville / Palmyra	41.87

Low Temp	2.46
Medium Temp	69.97
High Temp	27.57

	% Coverage
Winthrop / Bateman	32.49

Low Temp	0.48
Medium Temp	82.39
High Temp	17.13

	% Coverage
Applecross	42.06

Low Temp	1.4
Medium Temp	65.59
High Temp	33.01

	% Coverage
Murdoch / Leeming	24.31

Low Temp	1.15
Medium Temp	78.56
High Temp	20.29

	% Coverage
Myaree	37.9

Low Temp	7.02
Medium Temp	65.36
High Temp	27.62

Building coverage appears to have a fairly strong correlation with percentage of high temperature areas. When you rank percentage of building coverage you have;

1 - Applecross
2 - Bicton/Melville/Palmyra
3 - Myaree
4 - Winthrop/Bateman
5 - Murdoch/Leeming

And when you rank the study areas in terms of percentage of high temperature coverage you have;

1 - Applecross
2 - Myaree
3 - Bicton/Melville/Palmyra
4 - Murdoch/Leeming
5 - Winthrop/Bateman

Although the rank is slightly different, Myaree and Bicton/Melville/Palmyra are very close in both field, as are Winthrop/Bateman and Murdoch/Leeming. So there may be some correlation there.

5 CONCLUSIONS AND RECOMMENDATIONS

5. 1 Relationships determined

As discussed in 4.1.2, there may be some correlations between differing land coverage types and the heat intervals, however at this stage they look quite weak and what relations were discussed my just be down to coincidence.

When analysed qualitatively however, there do appear to be some very strong relationships between the colour of the surface or roofing and producing a temperature in the low heat bracket. This can be put down to the fact that light coloured objects have less capacity to absorb thermal radiation then those of darker colours and thus prevents theses light coloured objects from radiating hear into the night.

5. 2 Problems and Improvements

Due to the facts this project was unable to determine any strong correlations between the land coverage and the temperature intervals, it seems like maybe there was not enough detail designed into the planning of the data processing. This project divided the thermal image into three brackets of heat ranges, low, medium and high. This could have been improved by increasing the number of temperature brackets from three to four, five or possibly even six. Having these extra temperature ranges to work with may have given a greater scope of data to work with possibly allowing closer correlations between temperature and land usage to be determined.

Another improvement that could have been made is a simple one, and that would be to merge the three classes of vegetation coverage, low, medium and high, into one shapefile representing “all vegetation”. This data may well have had a better result because when you look at all the vegetation shapefiles overlapped on top of the heat map, you can see that together, they often form the boundaries between the medium heat zones and the high heat zones as briefly discussed in 4.1.1.

5. 3 Possible Further Studies

In 4.1.1, it was found that colour seemingly has a greater positive effect on the management of urban heat islands. This could be an interesting area to look into for future studies in the City of Melville. This would make use of all the remote sensing data provided by the City of Melville, and not just the thermal imagery. Areas of study such as colour of roofing and vegetation colour could be further analysed and compared to the thermal imagery in order to find possible relations between colour of coverage and temperature.

5. 4 Recommendations

The main conclusions that can be drawn from this project are that black asphalt road surfaces are clearly the areas in the City of Melville that have the highest surface temperatures. This may be an area where looking into lighter coloured asphalt could be beneficial (Synnefa, 2010).

It is also evident that increasing the overall proportion of vegetation coverage, and quite possibly, with most importance, high vegetation i.e. tall trees, as although the correlation for various vegetation classes and temperature were quite week, there is strong evidence that they do have a significant effect in stopping areas reach the highest heat bracket.

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