

Maroondah Canopy & Landscape Analysis 2011 to 2016

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June, 2018

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1. SUMMARY

This research report was commissioned by Maroondah City Council to undertake an analysis of Maroondah's canopy and landscape characteristics and provide insight into the effectiveness of planning controls in achieving intended objectives with a view to protect, enhance, restore or recreate Maroondah's canopy cover into the future. The findings from this research will facilitate Maroondah City Council's ability to develop evidence-based policy to deliver on commitments to the *Maroondah 2040: Our future together* (Maroondah City Council 2014) directions for "A Green Community".

The purpose of this research was to estimate canopy cover by public, streetscape and private areas, to estimate change in canopy cover and cover class, to identify the primary cause of change in canopy cover (construction/ removal) and to broadly identify areas for priority canopy cover planting. Results from the research indicate that between 2011 and 2016 the Maroondah Local Government Area (LGA) had a stable and relatively high (27.1%) urban tree canopy cover with no statistically significant ($p < 0.05$) growth or loss over the five year period. The stable tree canopy cover percentage however, was accompanied by high and significant increases to hard surfaces in private land across the LGA (+1.9%, $p < 0.05$) with an increase of 117 ha over five years, and significant decrease to grass/ bare earth at (-1.8%, $p < 0.05$), a decrease of 104 ha.

Canopy cover and canopy cover change within Maroondah LGA was not uniform and land use tenure was an important factor in canopy cover distribution. The highest canopy cover by land tenure in 2016 was in public space at 37.3% of the area, followed by private land (25.9%) and streetscapes (25.2%). Public space disproportionately contributed to canopy cover growth and private land was also a net contributor to canopy cover, particularly in areas subject to a Vegetation Protection Overlay (VPO). Canopy cover in areas beyond the VPO and subject to Schedules 1 or 2 to Design and Development Overlay (DDO1 and DDO2) however, experienced a net significant loss over the same period (-2.0%, $p < 0.05$). Further assessment into canopy cover change under the DDO1 or DDO2 (see aggregated spatial area 'DDO') indicate that there was slightly higher construction activity which resulted in some tree canopy loss. The net loss in canopy cover in the DDO however, was not due solely due to high canopy cover loss, but rather canopy cover growth over the five years did not compensate for losses and this could be from a variety of factors such as tree age and morbidity or lag time between planting of new trees and those new trees becoming large enough to be recognised as canopy.

Potential for tree planting on nature strips is greatest in Aggregate Spatial Areas 'SLO' and 'Other', with most (150 ha) of the potentially plantable land for street trees located in the former. Aggregate spatial area 'Other' supports the lowest street tree canopy cover (12.3%) and has high potential for additional tree planting with a plantable area that is 18.2% grass/bare earth.

Most of the significant changes, growth and loss, to canopy cover occurred in the ridgeline environments of the LGA

such as Spatial Areas 2, 3, 5 and 6 where DDO and VPO schedules are applied in addition to Schedule 3 to the SLO. While some areas of the ridgelines experienced significant loss in canopy cover over the five year period, it is important to acknowledge that the areas along the ridgelines continue to support some of the highest levels of canopy cover (32.7% AGA'DDO' and 42.1% AGA'VPO') in Maroondah and Melbourne, and this is despite the significant landscape changes observed over the same time period.

One of the most consistent and significant findings in this research was the increase in hard surfaces and the decrease in grass/ bare earth and shrubs. This suggests that the intensity of land use in Maroondah is shifting to the provision of constructed environments and tree centered ecosystem services at the expense of lawns, garden areas and open land.

2. INTRODUCTION

The purpose of this research is to estimate canopy cover by public, streetscape and private areas, to estimate change in canopy cover and cover class, to identify the primary cause of change in canopy cover (construction/ removal) and to broadly identify areas for priority canopy cover planting.

Specific outputs from this research include:

- Sample based canopy cover percentages for Maroondah and each spatial area assessed (12 in total) by land-use area (public land, private space and streetscapes) for 2011 and 2016;
- Estimates of change in canopy cover between 2011 and 2016;
- Identification of potential cause of canopy cover loss, if any (construction/removal);
- Estimates of cover classes (hard, grass, shrub, tree) for each spatial area by land tenure; and
- The provision of a methodology to be able to assess change in canopy cover in the future.

3. BACKGROUND

Tree canopy cover is a simple measurement of the extent of the urban forest, and therefore an indicator of the magnitude of the ecosystem services provided by the forest (Nowak & Greenfield 2012). Benchmarking projects estimating urban tree canopy cover by Jacobs et al. (2014), Amati et al. (2017) and Kaspar et al. (2017) provide important examples of estimating and tracking change in canopy cover through different land tenures using the i-tree method. The work described in this report and its appendices draws on and contributes to the methodology used in those reports to further the understanding of change in tree canopy cover and other landscape features in the Maroondah LGA.

Trees and tree canopy cover in urban areas

Trees provide ecosystem services that have physical, biological and social benefits ranging from air purification (Weber et al. 2014; Nowak 2002), temperature regulation (Hardin & Jensen, 2007), increased property prices (Smardon, 1988;

Tyrvaïnen & Miettinen, 2000; Sander et al. 2010), storm water attenuation (Roy et al. 2012), psychological wellbeing (Fuller et al. 2007; Taylor et al. 2015), crime reduction (Kou & Sullivan 2001) and noise reduction (Gómez-Baggethun & Barton, 2013). Because of these factors, many local governments have committed themselves to increasing canopy cover. Urban areas are constantly in flux and tree cover can change dramatically, particularly in response to local government policy or planning controls, population increase and the almost universal increase in housing density and road networks (Hill et al. 2010; Brunner & Cozens 2013; Davies et al. 2008). These factors make it imperative that councils are able to easily and reliably measure and compare tree cover over time by differing geographic and policy relevant areas.

Maroondah Planning Scheme and reference documents

The Maroondah Local Planning Policy Framework (LPPF) and Municipal Strategic Statement (MSS) focus strongly on landscape and associated matters including the retention of a canopy tree dominated landscape. This is reflected conspicuously through the Significant Landscape Overlay (SLO) – an overlay which has been applied extensively throughout the LGA. Previous research on tree canopy cover or other vegetation and landscape characteristics commissioned by Maroondah City Council include *Assessment of the Tree Canopy Cover in the City of Maroondah* (1995), *Notable Trees of Maroondah* (1997) and *Open Space Requirements for Provision and Retention of Canopy Trees in Maroondah* (2002) which are reference documents contained in the Maroondah Planning Scheme.

Research 2011-2016

The outputs from this research draw on the methodology developed in previous canopy cover sampling research and estimate the change in canopy cover and cover classes in Maroondah LGA between 2011 and 2016 by the spatial areas developed to reflect the application, or absence, of planning controls intended to influence landscape and environment management (VPO, SLO and DDO) and by land tenure (streetscapes, public space, private land). The ultimate aim of the project is to provide data on canopy cover and canopy cover change in Maroondah to inform canopy cover policy into the future.

4. METHODOLOGY

The research methodology for this report was conducted consistent with previous tree canopy cover benchmarking assessments completed by Jacobs et al. (2014), Amati et al. (2017) and Kaspar et al. (2017) based on the i-tree method. A dependent sample of 2000 random points in QGIS was used to classify landscape features of remote imagery for each spatial area in Maroondah (11 spatial areas plus the LGA as a whole) for both 2011 and 2016. Each sample point was assessed as either one of four variables: Tree canopy cover (1), Shrub cover (2), Bare earth/ grass (3), or Hard surface (4) and coded as streetscape, private land or public space. If change was recorded between 2011 and 2016 an additional assessment of the area was made to ascertain the cause of the loss. Each point classified as tree canopy was additionally assessed as native or exotic tree species and outputs assessed for standard error and statistical significance.

Statistical boundaries

Maroondah as a whole and 11 subset polygons sourced from Maroondah City Council were assessed for the research (Table 4.1 and Figure 4.1). The subsets were based on disaggregates of Vegetation Protection Overlay (VPO), Significant Landscape Overlay (SLO), Design and Development Overlay (DDO), a previously applied Local Law and areas where these controls have not been applied (Newbiggin, 2018).

The following four aggregate spatial areas are used in this study:

- *Aggregate Spatial Area 'VPO' (ASA'VPO')* includes spatial areas 2, 3 and 4 which are each subject to a *Vegetation Protection Overlay (VPO)*. The objective of the VPO is to protect and enhance areas of biological significance in Maroondah so as to ensure the maintenance and enhancement of the biological diversity of the flora and fauna of Maroondah and enhance the presence of indigenous species in the natural environment.
- *Aggregate Spatial Area 'DDO' (ASA'DDO')* includes spatial areas 5 and 6 which are subject to a *Design and Development Overlay (DDO)* but are not affected by a VPO. The DDOs set specific requirements relating to design of new subdivision. The two key ridgelines in the LGA, the Loughnan and Wicklow Hills ridgelines, are protected by minimum lot sizes requirements of Schedules 1 (DDO1) and 2 (DDO2) of the DDO. Schedule 7 (DDO7) also contains relevant controls but is limited to northern gateway area.
- *Aggregate Spatial Area 'SLO' (ASA'SLO')* includes spatial areas 7, 8, 9 and 10 which are subject *Significant Landscape Overlay (SLO)* but are not affected by any VPO or DDO. Maroondah's SLOs (of which there are four schedules) sets permit requirements to remove, lop or destroy canopy sized trees (threshold dimensions for a permit being 5 m height or 0.5 m stem circumference). Schedule 3 (SLO3) to the SLO identifies canopy vegetation as the main and valued urban character element in Maroondah due to its '*continuous nature*' on ridgelines, its softening impact on buildings in the environment and its biodiversity contribution as wildlife movement corridors, habitat and shelter areas. Schedule 4 (SLO4) contains similar statements regarding canopy vegetation in combination with steep to undulating topography. All four schedules to the SLO place similar value on canopy vegetation.

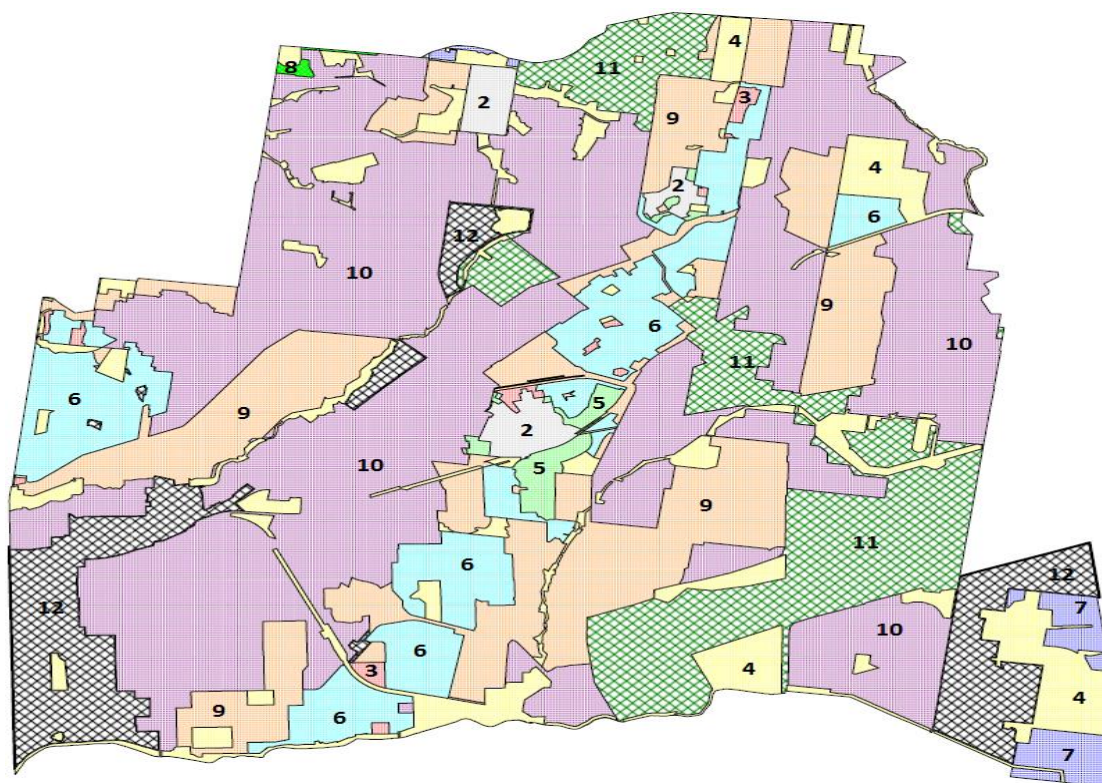
- *Aggregate Spatial Area 'Other' (ASA 'Other')* includes spatial areas 11 and 12 which are subject to no planning overlays. ASA 'Other' is an aggregation of spatial area 11, an area formerly subject to Local Law Number 5 – Public safety and amenity (the Local Law) which was operative from 01/01/2000 to 31/12/2009, and spatial area 12 where no controls have been applied. The Local Law prohibited removal, destruction or lopping of a canopy trees in a designated area without first obtaining a permit.

Table 4.1. *Spatial areas assessed for the Maroondah Canopy & Landscape Analysis*

Aggregate Spatial Areas (AGA)	Spatial Areas	Spatial area description	Area Ha*	% of Maroondah*
LGA	Area 1	Maroondah LGA	6140	100
VPO			728	11.9
	Area 2	VPO1 overlap with DDO1	87	1.4
	Area 3	VPO1 overlap with DDO2	28	0.4
	Area 4	VPO1 no overlap with DDO1 or DDO2	614	10
DDO			618	10.1
	Area 5	DDO1 no overlap with VPO1	50	0.8
	Area 6	DDO2 no overlap with VPO1	568	9.2
SLO			3675	59.9
	Area 7	SLO1 no overlap with VPO1 DDO1 DDO2	84	1.4
	Area 8	SLO2 no overlap with VPO1 DDO1 DDO2	5.2	0.1
	Area 9	SLO3 no overlap with VPO1 DDO1 DDO2	1080	17.6
	Area 10	SLO4 no overlap with VPO1 DDO1 DDO2	2506	40.8
Other			1170	19.0
	Area 11	Local Law no overlap with VPO1 DDO1 DDO2 SLO1-4	712	11.6
	Area 12	No Controls	458	7.5

*Area will not equal 100% due to minor level of overlap (0.8%) in the overlays.

Figure 4.1. Maroondah LGA and overlay assessment areas



Land tenure classification

Land tenure areas were classified based on land use: private land, public space or streetscapes (Table 2.2 below). Areas were aggregated using zoning data and polygons from the *Vicdata* planning database (Vicdata 2016). Tenure types included the following:

- *Streetscapes*: streets, roads, alleyways and nature strips and is mostly an area under the jurisdiction of local government or road management authorities (i.e. Council or VicRoads);
- *Public space*: areas under local, state or federal government, for example parks, libraries, cemeteries and education facilities; and
- *Private land*: commercial, industrial, residential and other land use types.

Table 2.2. Land tenure categories from *Vicdata* planning database used in the study

Tenure	Zoning code	Zoning class description
<i>Public</i>	PC, PP, PU	Public Park, Education, Health and Community, Transport, Cemetery Crematorium, Local Government, Conservation Zone, Other public use or service area
<i>Private</i>	AC, AE, B, BM, C, CA, CC, CD, CL, D, DC, DD, DP, DZ, EA, EM, ER, ES, FO, FZ, GA, GR, GW, HO, IA, IN, IP, LD, LS, MA, MU, NC, NR, PA, PD, PZ, R, RA, RC, RF, RG, RL, RO, RU, RX, SB, SL, SM, SR, SU, TZ, UF, UG, UR, VP, WM	Commercial, Industrial, Residential, Other land-use types
<i>Street</i>	RD	Streets, Roads, Nature Strips

Table 2.3. *Classification of variables*

Tree Canopy	Shrub Canopy	Grass/ Bare Earth	Hard Surface
- o Tree that is >3 metres - o Any plant that looks like a tree from above	- Plant that is <3 metres but not grass - o Agricultural crops such as grape vines - o Bush land shrubs	- o Agricultural pasture - o Residential lawns - o Cleared areas to the sides of roads and railway tracts - o Golf Courses - o School Ovals - o Grasslands - o Sports Fields - o Cemeteries - o Horse racing tracks - o Lawn Bowls - o Grass Tennis Courts - o Sites cleared for development - o Dirt roads and walking tracks	- o Buildings - o Roads - o Footpaths - o Train lines - o Car parks - o Water bodies - o Sandy beaches - o Rocky coastlines

Source: Jacobs 2014

Identifying trees from shrubs

The aim for the project was to classify trees with a canopy height greater than three metres. There is no definitive method to identify a tree from a shrub in an aerial image due to the two-dimensional nature of the remote images used (Rogers & Jaluzot 2015). However, similar to other research on canopy cover, shadows, growth over fences and buildings and other contextual information can be used to help differentiate between trees and shrubs (Richardson & Moskal 2014). Research from Parmehr et al. (2016) indicate that the results from a 1000 point sample are within statistical significance parameters when the i-tree method is compared with other canopy cover estimation methods such as Light Detection And Ranging (LiDAR) and multi-spectral imagery, thus non sampling error from the misclassification of shrubs and trees with a 2000 point sample per area as used in this report will be minor.

Other potential sources for misclassification include excessive shadows resulting from the time of the day the remote image was taken, user error and vegetation height. Vegetation height, coupled with the angle that the image was taken can potentially lead to image parallax errors where tall objects appear to lean and 'move' the point between the two time images (Nowak & Greenfield 2012).

Assessing the cause of canopy cover loss

A dependent sampling regime was used for this research i.e. the same sample was used for each time period, which enables a statistical assessment of the cause of loss of canopy cover from time A to time B. For example, if a point was classed as Tree (1) in 2011 but then classed as Not Tree (2-4) in 2016, then an additional visual assessment of both aerial images around the point was done to identify the cause of the loss. A new variable captured this with two values; one value identifying the general cause of the canopy cover loss: construction or removal, a second value identifying potential parallax/ aspect and thus data quality for comparisons (see Figure 7.1 in Section 9: *Data quality, interpretation and comparisons*).

- *Construction*: identified as the cause if there was evident building activity in the surrounding area of canopy loss (for example renovation, a new building/pool);

- *Removal*: identified as the cause if there was no direct identifiable cause of the canopy loss (for example tree pruning, tree death or tree removal); and
- *Parallax/ Aspect*: identified as the cause if the tree appeared to move between times due to the angle of the image taken and was used as a variable to indicate data quality for comparisons.

Assessing tree species composition

An additional assessment of each point classified as tree canopy was assessed for broad tree species category and coded as either (1) *Eucalyptus/ Melaleuca/ Acacia*; or (2) *Other species* (which are used as an indicative proxy for exotic species).

Statistical tests and error

Two types of error can occur in data resulting from the samples and data sources used in this report: *non-sampling error* and *sampling error*.

Non-sampling error can occur at any stage of data collection and is primarily a result of processing error through incorrect coding, time period bias for the aerial imagery, image parallax or inconsistency of the classification of points. These issues were largely mitigated through checking, careful assessment of points, ensuring image time consistency (time of year) and the creation of a parallax/ aspect variable as an indicator of data quality for comparisons between time points.

Sampling error is the difference between the sample estimate derived and the 'true value' if a full mapping project of the canopy cover were actually to be conducted (McLennan 1999). The two core factors affecting sampling error in this report included:

1. Sample size: Larger samples give rise to smaller sampling error;
2. Sample/ canopy proportion ratio: The larger the sample is as a proportion of the actual canopy cover, the smaller will be the sampling error.

Two methods were used to estimate sampling error:

1. Calculation of the standard error for each proportion for each indicator; and
2. Testing for significance (p) in comparisons of the sample derived cover class proportion between each time point through McNemar test.

For more information on data processing, quality and interpretation see Section 9: *Data quality, interpretation and comparisons*.

4. OUTCOMES

Spatial areas and land use types

Most land was classified as private according to the land use typology used in the report which includes residential, industrial and commercial land; Maroondah LGA comprises 71.5% private land (4390 ha in total) and the spatial areas had private land preponderance ranging from 90.2% in Area 3 to 50.6% in Area 4 (both in VPO). Streetscapes ranged from 21.4% of the land area in Area 10 to 4.9% in Area 7 (both in SLO). Public space had variable area particularly by spatial area, Maroondah LGA has 10.9% public space (669 ha) in total but in the spatial areas, public space ranged from negligible (0.1%) in Area 7 (DDO) to more than two fifths (43.8%) of Area 4 (VPO).

Table 4.1. *Distribution of land-use types by spatial area, 2016*

Aggregate Spatial Areas (AGA)	Spatial Area	Spatial area description	Streetscape		Private land		Public space		Total	
			%	ha	%	ha	%	ha	%	ha
LGA	Area 1	Maroondah LGA	17.7	1087	71.5	4390	10.9	669	100	6140
VPO		Vegetation Protection Overlay	6.8	50	55.9	407	37.4	272	100	728
	Area 2	VPO1 overlap with DDO1	12.0	10.4	84.1	73.2	4.0	3.5	100	87
	Area 3	VPO1 overlap with DDO2	7.6	2.1	90.2	25.3	2.3	0.6	100	28
	Area 4	VPO1 no overlap with DDO1 or DDO2	5.6	34.4	50.6	310.7	43.8	268	100	614
DDO		Design and Development Overlay	16	99	83.8	518	0.2	1.0	100	618
	Area 5	DDO1 no overlap with VPO1	17.5	8.8	81.7	40.9	0.9	0.5	100	50
	Area 6	DDO2 no overlap with VPO1	16.2	92.0	83.8	476.0	0.1	0.6	100	568
SLO		Significant Landscape Overlay	20.7	761	71.8	2639	7.4	272	100	3675
	Area 7	SLO1 no overlap with VPO1 DDO1 DDO2	4.9	4.1	95.1	79.9	0.1	0.1	100	84.0
	Area 8	SLO2 no overlap with VPO1 DDO1 DDO2	18.4	1.0	57.1	3.0	24.6	1.3	100	5.2
	Area 9	SLO3 no overlap with VPO1 DDO1 DDO2	18.0	194.4	73.3	791.6	8.8	95.0	100	1080
	Area 10	SLO4 no overlap with VPO1 DDO1 DDO2	21.4	536.3	70.7	1771.7	8.0	200	100	2506
Other		Local Law/ No controls	15.7	184	71.7	839	12.7	149	100	1170
	Area 11	Local Law no overlap with VPO1 DDO1 DDO2	14.2	101	72.6	517	13.3	95	100	712
	Area 12	No Controls	17.9	82	69.3	317	12.9	59	100	458

Canopy cover in Maroondah by spatial area

In 2016 Maroondah LGA had 27.1% ($\pm 1.0\%$) canopy cover and experienced a 0.8% increase of canopy cover since 2011 however, this change was not statistically significant ($p=0.24$). Aggregate spatial areas 'VPO', 'DDO' and 'SLO' all had a high canopy cover ranging from 42.1% ($\pm 1.1\%$) in ASA 'VPO', followed by ASA 'DDO' at 32.7% ($\pm 1.0\%$), to 22.6% ($\pm 0.9\%$) for ASA 'SLO'. ASA 'Other' which included a large amount of industrial and commercial areas had canopy cover at less than half the average for the ASAs at 9.7% (Table 4.2 below). Area 2 (VPO1 overlap with DDO1) had the highest canopy cover of all the spatial areas tested in Maroondah in 2016 at 56.8% ($\pm 1.1\%$); while the lowest estimate for canopy cover was for Area 12 (No controls) at 8.4% ($\pm 0.6\%$).

Table 4.2. Canopy cover by spatial area in Maroondah, 2011 to 2016

Aggregate Spatial Areas (AGA)	Spatial Area	Spatial Area description	2011		2016		Change	
			%	se	%	se	%	p
LGA	Area 1	Maroondah LGA	26.2	1.0	27.1	1.0	0.8	0.24
VPO			41.2	1.1	42.1	1.1	1.0	0.25
	Area 2	VPO1 overlap with DDO1	50.6	1.1	56.8	1.1	6.2	0.01
	Area 3	VPO1 overlap with DDO2	47.5	1.1	54.2	1.1	6.8	0.01
	Area 4	VPO1 no overlap with DDO1 or DDO2	37.2	1.1	37.7	1.1	0.5	0.54
DDO			34.6	1.1	32.7	1.0	-2.0	0.01
	Area 5	DDO1 no overlap with VPO1	44.7	1.1	44.0	1.1	-0.7	0.43
	Area 6	DDO2 no overlap with VPO1	33.0	1.1	31.0	1.0	-2.0	0.01
SLO			22.5	0.9	22.6	0.9	0.1	0.88
	Area 7	SLO1 no overlap with VPO1 DDO1 DDO2	16.7	0.8	18.8	0.9	2.1	0.01
	Area 8	SLO2 no overlap with VPO1 DDO1 DDO2	33.5	1.1	32.9	1.1	-0.6	0.37
	Area 9	SLO3 no overlap with VPO1 DDO1 DDO2	25.4	1.0	24.0	1.0	-1.4	0.07
	Area 10	SLO4 no overlap with VPO1 DDO1 DDO2	21.4	0.9	21.6	0.9	0.2	0.81
Other			9.4	0.7	9.7	0.7	0.3	0.60
	Area 11	Local Law no overlap with VPO1 DDO1 DDO2 SLO1-4	10.8	0.7	12.0	0.7	1.3	0.03
	Area 12	No Controls	8.7	0.6	8.4	0.6	-0.4	0.49

Change in canopy cover

AGA'VPO' had the highest canopy cover growth of the aggregate spatial areas between 2011 and 2016 (+1.0%), followed by ASA'Other' (+0.3%) and ASA'SLO' (+0.1%). Canopy cover in ASA'DDO' decreased by -2.0% ($p < 0.05$) down from 34.6% in 2011 to 32.7% canopy cover in 2016.

Area 3 and Area 2, each subject to a VPO1 in combination with DDO and SLO schedules, had large and significant ($p < 0.05$) canopy cover growth, +6.8 and +6.2% respectively, followed by Area 7 (where only a SLO1 is applied) +2.1% and Area 11 (an area without planning scheme overlays but which was previously subject to a Local Law) +1.3%. Area 6 (DDO2 and SLO3 apply without any VPO) constitutes more than 90% of ASA'DDO' and recorded a significant ($p < 0.05$) loss in canopy cover between 2011 and 2016 (-2.0%).

Figure 4.1. Map of canopy cover in Maroondah by aggregate spatial area, 2016

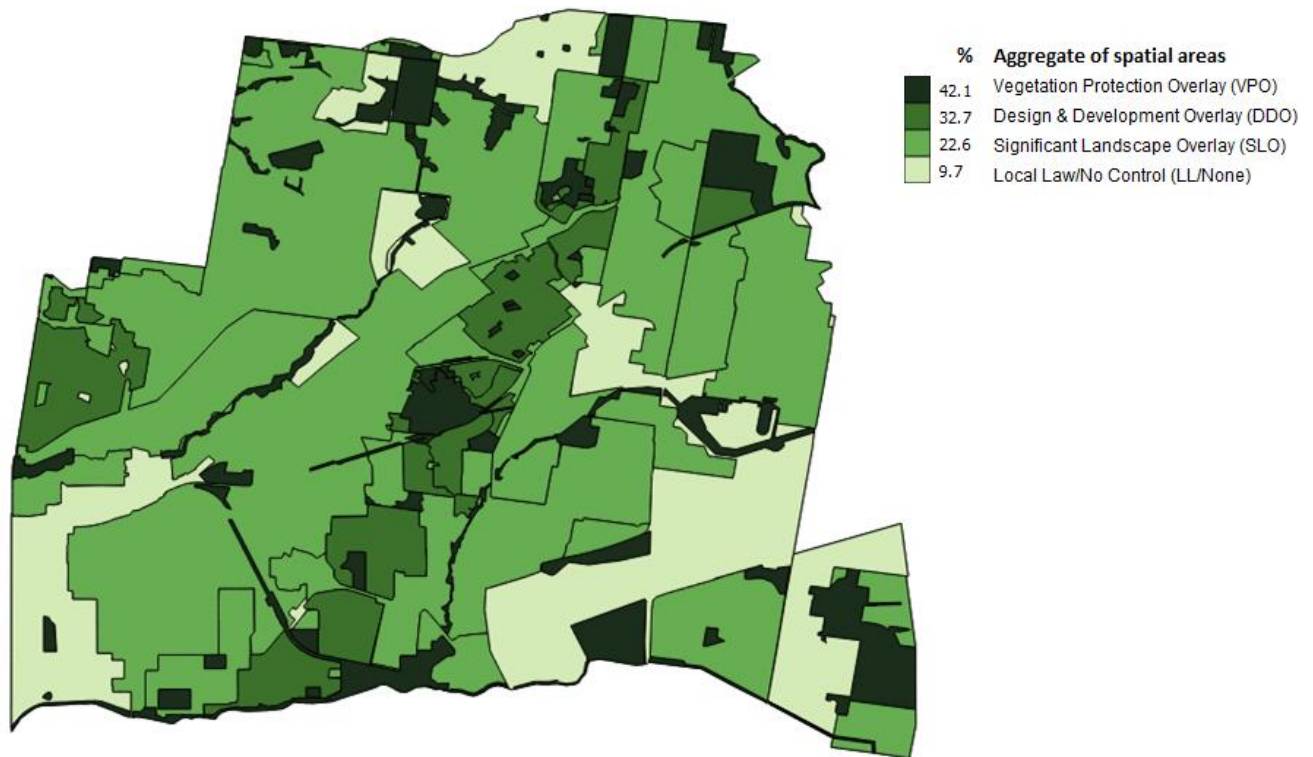
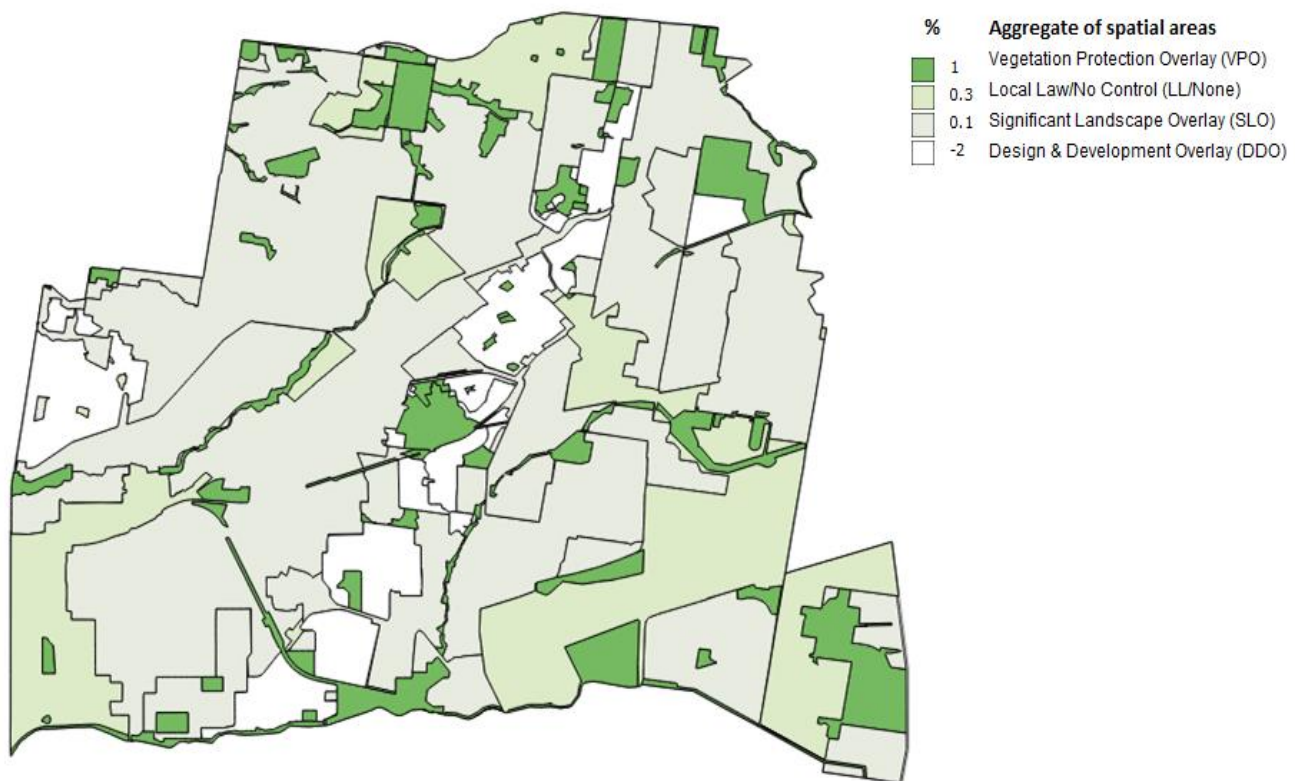


Figure 4.2. Map of change in canopy cover in Maroondah by aggregate spatial area, 2011-2016



Change in canopy cover by land-use area

Public space has the largest proportion of tree canopy cover in Maroondah at 37.3% ($\pm 3.3\%$), followed by private land (25.9%, $\pm 1.2\%$) and streetscapes (25.2%, $\pm 2.3\%$). The highest canopy cover by tenure estimated in the eleven subset areas of Maroondah is in public space in Area 3 (VPO1 overlap with DDO2) at (60.0%, $\pm 7.3\%$) and the lowest canopy cover estimate was for private land in Area 12 (No controls) at 14.8% ($\pm 2.2\%$).

The most significant dynamic change in canopy cover between 2011-2016 occurred on private land. A significant ($p < 0.05$) gain in canopy cover on private land was estimated for Area 3, Area 2 and Area 7 (+6.8%, +6.4% and +2.0% respectively) and significant loss (-2.0%, $p < 0.05$) was estimated for private land in Area 6 (DDO2 no overlap with VPO1). The sampling method on non-private land tenure (streetscapes and public space) could only detect significant change in Area 3 (VPO1 overlap with DDO2) streetscapes, which increased by +7.2% between 2011 and 2016, the largest significant increase in canopy cover estimated in this study. No significant change was estimated for public space in any of the spatial areas tested which may be due to the lower sampling size allocated to the smaller relative area (10.9% of Maroondah LGA) and not necessarily due to lack of canopy cover growth.

Table 4.3. *Change in canopy cover (%) by land-use area by overlay area, 2011-2016*

Aggregate Spatial Areas (AGA)	Spatial Area	Spatial Area description	Streetscapes				Private land				Public space			
			2016	Se	Change	p	2016	Se	Change	p	2016	Se	Change	p
LGA	Area1	Maroondah LGA	25.2	2.3	0.3	1.00	25.9	1.2	0.9	0.31	37.3	3.3	1.4	0.61
VPO			27.4	3.8	3.8	0.55	39.9	1.5	1.5	1.00	48.1	1.8	1.8	0.13
	Area2	VPO1 overlap with DDO1	52.3	3.2	4.6	0.09	57.6	1.2	6.4	0.00	53.2	5.6	6.3	0.23
	Area 3	VPO1 overlap with DDO2	50.7	4.1	7.2	0.04	54.4	1.2	6.8	0.00	60.0	7.3	4.4	0.69
	Area 4	VPO1 no overlap with	16.1	3.5	1.8	0.69	32.2	1.5	-0.9	0.46	46.8	1.7	1.9	0.11
DDO			32.2	2.6	2.6	0.44	32.7	1.1	1.1	0.01	n/a	n/a	n/a	n/a
	Area 5	DDO1 no overlap with VPO1	45.1	2.7	3.4	0.11	43.2	1.2	-1.6	0.10	n/a	n/a	n/a	n/a
	Area 6	DDO2 no overlap with VPO1	30.3	2.6	-1.5	0.42	31.2	1.1	-2.0	0.01	n/a	n/a	n/a	n/a
SLO			26.0	2.2	2.2	1.00	20.7	1.1	1.1	1.00	32.2	3.8	3.8	1.00
	Area 7	SLO1 no overlap with VPO1	14.3	3.5	1.0	1.00	19.0	0.9	2.2	0.00	n/a	n/a	n/a	n/a
	Area 8	SLO2 no overlap with VPO1	37.5	2.5	1.6	0.48	36.4	1.4	-1.1	0.30	21.2	1.8	-1.4	0.17
	Area 9	SLO3 no overlap with VPO1	21.7	2.2	-0.6	0.88	22.3	1.1	-1.6	0.06	42.9	3.7	-0.6	1.00
	Area	SLO4 no overlap with VPO1	27.2	2.2	2.3	0.18	19.1	1.0	-0.6	0.43	28.1	3.6	1.9	0.45
Other			12.5	1.9	1.9	0.39	7.3	0.7	0.7	0.90	19.4	2.5	2.5	1.00
	Area	Local Law no overlap with	17.7	2.3	2.5	0.14	9.3	0.8	0.7	0.34	20.7	2.5	3.0	0.08
	Area	No Controls	8.7	1.5	1.4	0.30	7.1	0.7	-0.5	0.41	14.8	2.2	-1.9	0.18

Net change and churn

Canopy cover is a dynamic indicator, thus canopy cover increased and decreased in all areas assessed in the study, with the net estimate presented potentially hiding high activity or 'churn' in canopy cover over the five year period (Table 4.4 below). Some areas experienced more churn than others with the cause of loss having different impacts on the net

change. The greatest churn in canopy cover was in ASA'SLO' where the apparent stable net change (+0.1%) was due to large growth in canopy cover (+4.7%) accompanied by large loss (-4.6%).

A component to the significant loss between 2011-2016 in ASA'DDO' (-2.0%, $p < 0.05$) was that canopy losses (-6.0%) in private areas and streetscapes were also accompanied by lower tree canopy growth (+4.1%) to result in a net loss. The ASA'SLO' experienced similar growth rates in canopy cover (+4.6%) to ASA'DDO' , but experienced losses of 4.7%, thus, the net loss in canopy cover identified in ASA'DDO' was higher loss of canopy cover relative to the identified levels of growth for the AGA. AGA'VPO' had high loss in canopy cover (-5.6%) similar to ASA'DDO' however, this loss was also accompanied by large canopy cover growth which resulted in net canopy cover growth.

Table 4.4. *Percent loss and gain (churn) in tree canopy cover between 2011 and 2016 by tenure and spatial area*

Tenure	Growth and loss		
	Decrease	Increase	Net change
Maroondah LGA			
Streetscapes	-4.5	4.8	0.3
Private land	-4.4	5.3	0.9
Public space	-2.8	4.1	1.4
Total	-4.3	5.1	0.8
AGA'VPO'			
Streetscapes	-3.0	5.2	2.2
Private land	-6.4	6.5	0.1
Public space	-4.8	6.8	2.0
Total	-5.6	6.6	1.0
AGA'DDO'			
Streetscapes	-5.0	3.4	-1.6
Private land	-6.2	4.2	-2.0
Public space	n/a	n/a	n/a
Total	-6.0	4.1	-2.0
AGA'SLO'			
Streetscapes	-5.8	6.0	0.2
Private land	-4.4	4.5	0.1
Public space	-3.4	4.0	0.7
Total	-4.6	4.7	0.1
AGA'Other'			
Streetscapes	-1.3	2.6	1.3
Private land	-2.2	2.3	0.1
Public space	-2.4	2.4	0.0
Total	-2.0	2.3	0.3

Cause of loss

In every spatial area assessed in the study, tree removal was the most common cause of loss for canopy cover (Table 4.5 below). Decrease in canopy cover from removal ranged from -3.8% in ASA'DDO' to -1.3% in ASA'Other'. ASA'DDO' lost more canopy cover to construction activity (-1.7%) than any other aggregate area, followed by ASA'VPO' (-1.2%). The lowest ratio between canopy cover lost by removal to canopy cover lost to construction was experienced in the aggregate of areas with no planning controls (2.0) and ASA'DDO' (2.2) indicating that construction activity had a higher impact on canopy cover loss in these two aggregate areas compared to all other spatial areas.

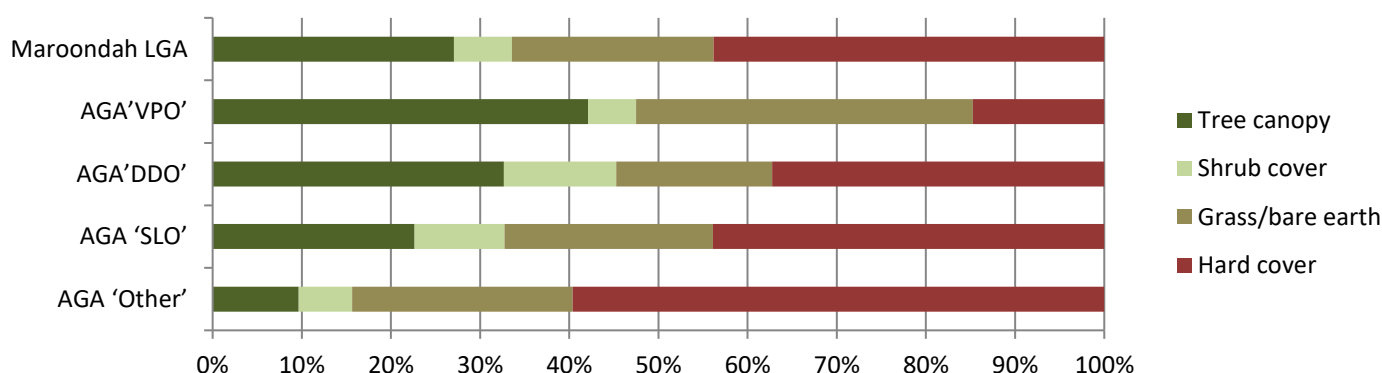
Table 4.5. Percent and ratio of loss in tree canopy cover between 2011 and 2016 by spatial area 2011-2016

Aggregate Spatial	Spatial Area	Spatial area description	Cause of canopy cover loss				Ratio of Removal to Construction
			Removal	Construction	Parallax	Total loss	
			%	%	%	%	Ratio
LGA	Area1	Maroondah LGA	-2.7	-0.8	-0.8	-4.3	3.6
VPO			-3.4	-1.2	-1.0	-5.6	2.8
	Area2	VPO1 overlap with DDO1	-3.7	-1.0	-1.1	-5.7	3.8
	Area 3	VPO1 overlap with DDO2	-3.3	-1.2	-0.5	-4.9	2.8
	Area 4	VPO1 no overlap with DDO1 or DDO2	-3.1	-1.2	-0.9	-5.2	2.6
DDO			-3.8	-1.7	-0.5	-6.0	2.2
	Area 5	DDO1 no overlap with VPO1	-4.2	-1.9	-1.0	-7.1	2.3
	Area 6	DDO2 no overlap with VPO1	-3.6	-1.8	-0.4	-5.7	2.1
SLO			-2.9	-0.9	-0.7	-4.6	3.1
	Area 7	SLO1 no overlap with VPO1 DDO1 DDO2	-1.2	-0.1	-0.6	-1.9	24.0
	Area 8	SLO2 no overlap with VPO1 DDO1 DDO2	-3.5	-0.2	-0.7	-4.4	23.3
	Area 9	SLO3 no overlap with VPO1 DDO1 DDO2	-3.9	-1.4	-0.5	-5.8	2.8
	Area 10	SLO4 no overlap with VPO1 DDO1 DDO2	-2.5	-0.8	-0.6	-3.8	3.3
Other			-1.3	-0.7	-0.1	-2.1	2.0
	Area 11	Local Law no overlap with VPO1 DDO1	-1.5	-0.7	-0.3	-2.4	2.3
	Area 12	No Controls	-1.2	-0.7	-0.3	-2.1	1.8

Cover class and dynamic change

The relative proportions of different types of land cover (trees, shrubs, grass/ bare or hard surface) vary substantially between the 11 subset spatial areas of Maroondah. This is largely a reflection of economic and social uses of the spatial areas or prevailing biophysical features. ASA'Other', which mainly encompasses industrial, business/commercial and residential areas, recorded the highest hard surface proportion at 59.6% ($\pm 1.1\%$), whereas AGA'VPO', which includes a large proportion of Maroondah's public space and parklands, recorded the lowest hard cover proportion at 14.8% ($\pm 0.8\%$), and the highest proportion of grass/ bare earth (37.8%, $\pm 1.1\%$).

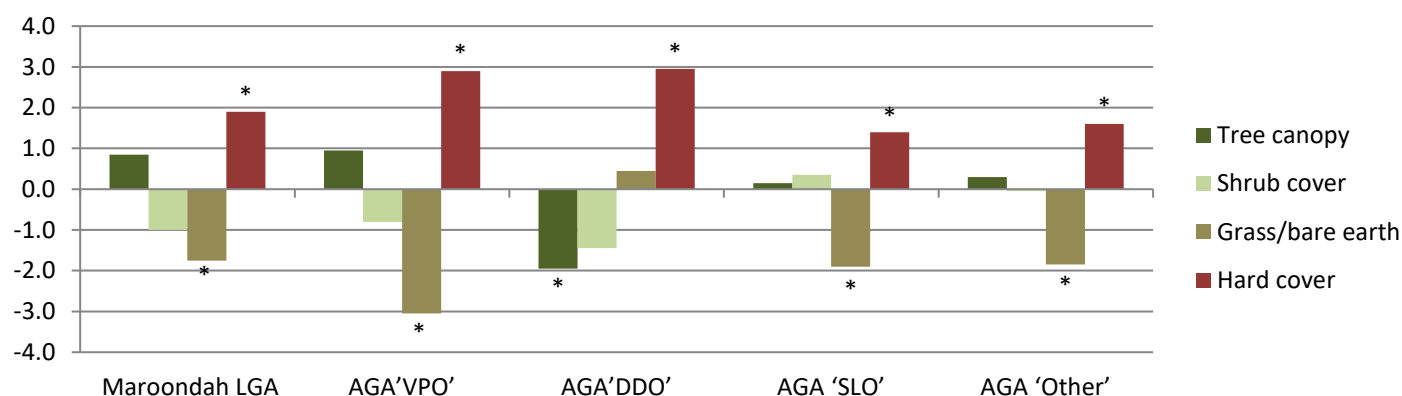
Figure 4.3. Cover class in 2016 by aggregate spatial area



The most consistent and significant ($p < 0.05$) estimates across all spatial areas, except for Area 3 (VPO1 overlap with DDO2), was the growth of hard surfaces over the 2011 and 2016 period. The growth in hard surfaces was at the expense of grass/ bare earth in most areas with the exception of AGA'DDO' where significant loss (-2.0% , $p < 0.05$) in

tree canopy cover was estimated and grass/ bare earth did not decline significantly.

Figure 4.4. Change in cover class between 2011 and 2016 by aggregate spatial area



* Indicates that significant ($p < 0.05$) change was detected between 2011 and 2016

Since 2011 to 2016 it is estimated that an additional 117 ha of hard surface was added to Maroondah LGA and this was largely at the loss of 104 ha of grass/ bare earth. A large proportion of all the hard surfaces (44% of the total) in Maroondah LGA were added in the SLO (Table 4.6 below).

Table 4.6. Change in hard cover and grass/ bare earth by percent and aggregate spatial area, 2011-2016

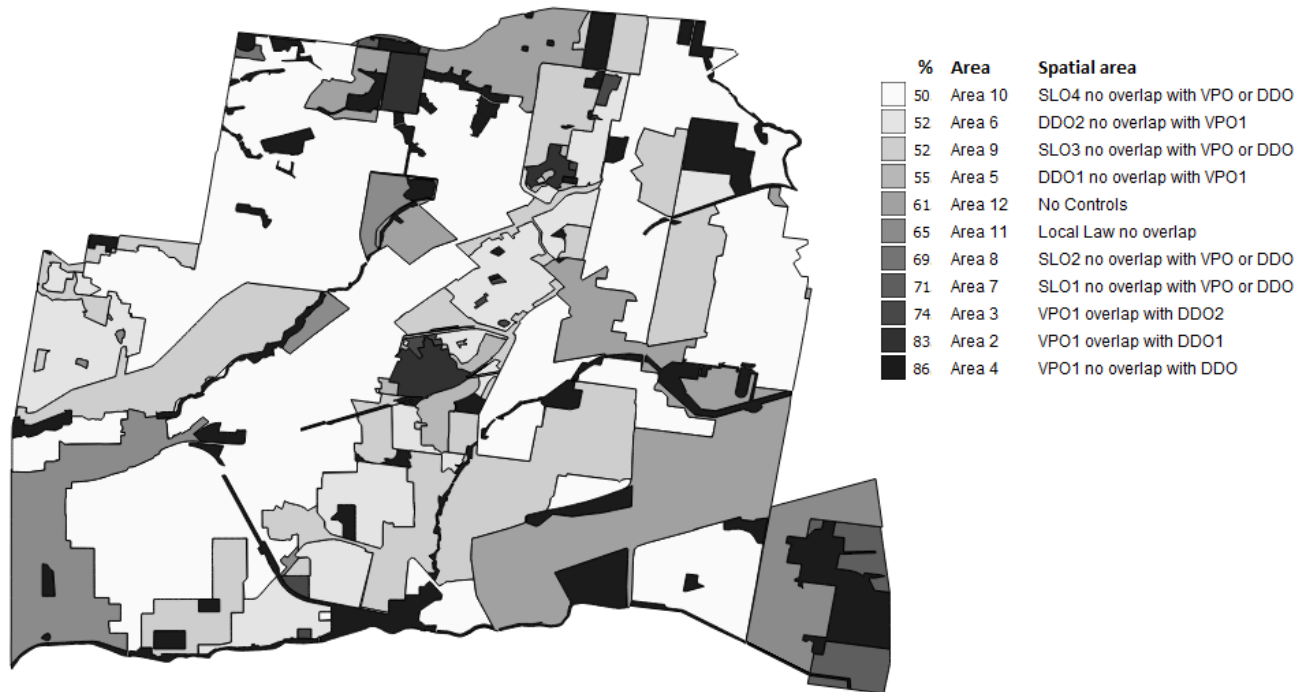
Aggregate Spatial area	2011			2016			Change	
	%	Se	Area ha	%	Se	Area ha	%	Area ha
Hard cover								
Maroondah LGA	41.9	1.1	2573	43.8	1.1	2689	1.9	117
'VPO'	11.9	0.7	86	14.8	0.8	108	1.4	21
'DDO'	34.3	1.1	212	37.3	1.1	231	3.0	18
'SLO'	42.5	1.1	1562	43.9	1.1	1614	2.9	51
'Other'	58.0	1.1	678	59.6	1.1	697	1.6	19
Grass/bare earth								
Maroondah LGA	24.4	1.0	1498	22.7	0.9	1394	-1.8	-104
'VPO'	40.8	1.1	297	37.8	1.1	275	-3.1	-22
'DDO'	17.1	0.8	105	17.5	0.8	108	0.4	3
'SLO'	25.3	1.0	929	23.4	0.9	860	-1.9	-69
'Other'	26.6	1.0	311	24.8	1.0	290	-1.9	-21

Tree species by spatial area

Canopy cover classified as native (*Eucalyptus/ Acacia/ Melaleuca*) was 59.6% of the sampled canopy of Maroondah and that proportion varied considerably between spatial areas (Figure 4.5). Area 4 (86%), Area 2 (83%) and Area 3 (74%) all under the VPO1, had the largest percentage of native canopy cover in Maroondah LGA. Area 10 (50%) and Areas 6 and 9 (both 52%) had the lowest proportion of native canopy cover. All spatial areas in Maroondah had a majority of canopy

cover (50% or more) classified as native.

Figure 4.5. Map of native (*Eucalyptus/ Acacia/ Melaleuca*) canopy cover in Maroondah by spatial area, in 2016



5. EVALUATION AND DISCUSSION

Canopy cover in 2016 and change

In 2016 Maroondah LGA had 27.1% ($\pm 1.0\%$) canopy cover which is a comparatively high canopy cover percentage for a Victorian LGA which has a median canopy cover percentage of 16.3% (Amati et al. 2017). Canopy cover and change in canopy cover was not uniform in Maroondah, 15% (911 ha) of the LGA has managed to achieve significant ($p < 0.05$) net growth with some areas located in AGA'VPO' averaging net growth in canopy cover as much as 6.4% to 6.8% ($p < 0.05$) since 2011. Most (77%, 4,661 ha) of Maroondah's land area however, experienced stable or no statistically significant ($p > 0.05$) net change over the five years (+0.5 to -1.4%) and 9% (568 ha) of the LGA experienced a significant ($p < 0.05$) net decrease in canopy cover by as much as -2.0% ($p < 0.05$).

Tenure and change

Private land

Many studies indicate that the general trend in the distribution and change in canopy cover in urban areas is largely affected by land use or tenure i.e. public space, private land or streetscape (Mincey et al. 2013). Most studies find a net

stable or net growing canopy cover in public space and streetscapes and a stable or net loss in canopy cover on private land. Private land is almost universally the larger proportion of most municipalities, thus the risk of higher absolute loss for the whole area is considerable. In Maroondah however, the estimated canopy cover on private land was not always in decline and private land recorded a net increase in canopy cover which was significant in several spatial areas, particularly those subject to a VPO (Table 4.3). Conversely, the only significant canopy cover losses were identified on private land subject to the DDO2 and the SLO3 (Area 6).

Public space

Public space was an important and disproportionate contributor to the total net canopy cover gains in Maroondah and for particular areas overall. This is consistent with previous research elsewhere indicating that public land is a major contributor to net canopy cover and net canopy cover growth in urban areas undergoing rapid infill development (Kaspar et al. 2017; Dobbs et al. 2013; City of Sydney, 2012).

Streetscapes, nature strips and plantable areas

The proportion of canopy cover on streetscapes ranged from 52.3% in Area 2 (VPO1 overlap with DDO1) to 8.4% in Area 12 (No controls) and was largely a reflection of the canopy cover composition of the total spatial area. No significant net change was estimated in canopy cover for streetscapes in Maroondah by any of the spatial areas except for Area 3 (VPO1) which may be due to the smaller sample size being allocated to the smaller area. Minimal change may also mean that there may be room for more street tree plantings, particularly in non VPO areas. The large highways that cross Maroondah (Eastlink, Mt Dandenong Rd, Maroondah Hwy) may make street planting difficult due to a larger proportion of the streetscape area being hard surfaces: 55.8% for Maroondah as a whole and as high as 66.8% for the 'Other' (Local Law/ No control) aggregate spatial area.

Traditional methods of identifying plantable areas for street trees use the cross analysis of areas that are pervious versus impervious with pervious areas identified as suitable areas for planting (Wu et. al 2008). The limited scope of the research presented in this report has not allowed for identification of specific areas suited for tree planting however, the research can provide some general insight into spatial areas where there are streetscapes that have a large amount of grass bare/ earth or low canopy cover and potential to plant more street trees. As table 5.1 below indicates, the largest room for more tree planting in Maroondah streetscapes is in AGAs 'SLO' and 'Other', with most (150 ha) of the potentially plantable land for street trees located AGA'SLO'. The greatest relative opportunity for street tree planting projects however, is in AGA'Other' as it has the lowest street tree canopy cover (12.5%) and potential room for planting (18.2% grass/bare earth).

Table 5.1. *Estimated potential tree planting area on nature strips in Maroondah by aggregate spatial area*

Aggregate spatial area	Total Streetscape area		Streetscape canopy cover		Nature strip area*	
	%	ha**	%	ha**	%	ha**
LGA	17.7	1087	25.2	274	15.6	169
'VPO'	6.8	50	27.4	14	16.3	8
'DDO'	16.0	99	32.2	32	19.4	19
'SLO'	20.7	761	26.0	198	19.8	150
'Other'	15.7	184	12.5	23	18.2	33

*Bare earth/ grass on streetscape tenure

**ha will not total 100% due to small sample size for streetscapes and is only an approximate indicator

Researching plantable areas for non-streetscape tenure such as public space would require more detailed sampling and assessments as the higher proportion of grass/ bare earth in public space would also coincide with the open space, sports fields and garden functions that public space provides. Further research into plantable space for private tenure subsections such as commercial areas however, may also be an option, with the potential to identify target sites in commercial areas where there is room for tree planting projects.

Spatial areas in Maroondah and canopy cover

There is little research on the impact that zoning, or indeed planning overlays and other planning controls, has on canopy cover, with most studies focusing on land use tenure (public space, private land, streetscapes) (Mincey et al. 2013). This research has shown however, that overlays applied to private land for the purpose of managing vegetation removal are associated with significant canopy cover growth. Where the Vegetation Protection Overlay (VPO), for example, has been applied in Maroondah significant growth has been experienced (Area 2 and Area 3) despite large and significant increase in hard cover throughout the LGA including where the VPO applies.

In areas subject to the Design and Development Overlay beyond the range of any Vegetation Protection Overlay (AGA'DDO'), there was significant net loss in canopy cover (-2.0%) and there are many factors that may be associated with this. Net tree canopy cover loss in an area is not always primarily due to land clearing or development. Ageing trees can also be a factor in slower growth rates as single age stands of trees reach the end of their life span, stabilize growth or die and get replaced. Studies have shown that the annual mortality rates for trees in urban environments, particularly streetscapes, ranged from 3-10%, and the most common cause of morbidity was age or hydric stress (Limoges et al. 2018). Tree age and natural attrition, i.e. 'removal' was a major factor in canopy cover loss (60-80%) throughout the LGA regardless of area. As presented in table 4.4 the significant net loss in canopy cover in AGA'DDO' was not necessarily due to unusually high canopy cover loss. For example, AGA'VPO' lost a percentage of canopy cover (-5.6%) similar to the loss in AGA'DDO' (-6.0). Thus an important factor in the net canopy cover loss in AGA'DDO' appears to be that canopy cover growth was not able to keep up with canopy cover loss (Table 4.5).

Mapped information in Figure 4.2 and in the supplementary maps indicate that much of most significant changes, loss or growth, to canopy cover have occurred in the ridgeline environments of the LGA. It is important to recognise however, that these same ridgeline environments, located primarily in AGAs 'VPO' and 'DDO', continue to support the highest levels of canopy cover in Maroondah (32.7 % and 42.1%) and have also seen a large increase in building activity which indicates that development policy regulating tree loss is having a positive effect in these areas.

Cover classes

Quantifying cover classes for Maroondah offer an opportunity to assess the magnitude, distribution and interrelationships landscape variables have in the LGA. The relationship between tree canopy and impervious (hard) cover or impervious cover and grass bare/ earth is particularly important for other broader environmental landscape indicators, issues and processes such as the urban heat island effect (UHI), hydrological processes, biodiversity and potential areas for tree canopy cover plantings or development works.

New housing is identifiable as a major contributor to hard surface cover which has increased by approximately 1.9% over the period assessed, however, new housing development is not the only factor in hard cover increase: the expansion of driveways, verandas or small scale refurbishment also aggregates up to the total hard surface area and was particularly evident in this study overall.

There is much research to show that local tree loss is one of the negative consequences of urban densification as trees are removed to make way for buildings and other impervious surfaces (Brown et al. 2013; Hostetler et al. 2013; Hall 2010; Brunner & Cozens 2013; Davies et al. 2008). What this research has shown however, is that the large amount of development that occurred from 2011 to 2016 mostly relates to an increase of hard surfaces and the loss of bare earth/ grass and not necessarily to a significant net reduction in canopy cover for the LGA as a whole. One of the most consistent and significant findings in this research was the increase in hard surfaces, regardless of spatial area, ranging from (+3.1% to +0.6%) and this increase was coupled with a decrease in grass/ bare earth (-0.8% to -4.3%) in almost all areas. For Maroondah as a whole, hard surface increased by +1.9% to reach 43.8% of the LGA area and grass/bare earth declined by -1.8% to 22.7%. Shrub layers similarly declined over the period and canopy cover increased over the same time period by +0.8%. This may suggest that the intensity of land use in Maroondah is primarily focused on the provision of constructed environments and tree centered ecosystem services which is happening primarily at the expense of lawns, low height garden areas and open grassed expanses.

Hard surfaces, canopy cover and broader environmental landscape indicators and processes

Air temperatures are frequently higher in urban areas than surrounding areas, this phenomenon known as Urban Heat Island index is a result of different landscape features such as impervious materials with low albedo storing heat and lowering evapotranspiration. UHI results in increased energy consumption, pollution and higher heat stress issues for

humans and the natural environment (Graham et al 2016; Loughner et al. 2012). The role that canopy cover and hard surfaces interrelate to influence urban ambient temperature to create the UHI is important. The primary factor mitigating UHI on a landscape scale is through increasing tree canopy cover and irrigated green space (Gage & Cooper 2017), the primary causal factor in the UHI is increased impervious (hard) surfaces (Monteiro et al. 2016; Du et al 2017). During heat events the ratio of impervious surfaces to canopy cover has been found to explain 91% of temperature variance between urban areas (Coseo and Larsen 2014). The increase in hard surfaces in areas with already high hard surface area such as Area 11 (Local Law no overlap with VPO1 DDO1) and Area 12 (No control) at 56.3% and 60.2% respectively, coupled with below average canopy cover (12.0% and 8.4%) may be an area to focus on for further research.

Hard surface increase and hydrology

The urban landscape has a demonstrable impact on hydrological processes and this is primarily through impervious surfaces and the contribution they make to changing surface albedo, thermal properties, water channeling and drainage (Arnold & Gibbons 1996; McGrane 2016). While this study makes no attempt to measure usual hydrological indicators such as Directly Connected Impervious Area (DCIA), research has shown that even small increases in hard surfaces can impact on hydrology, including influencing considerably higher peak discharges.

6. SUGGESTED FURTHER WORK / RESEARCH

This benchmarking research provides a wealth of further questions and policy implications for further research into canopy cover, cover classes and the interaction with other landscape, social and environmental factors. Potential further research subjects may include:

- Estimates of the potential impact changes in hard surfaces and canopy cover can have on the urban heat island effect and heat wave severity in Maroondah through small area impervious surface/canopy cover ratios;
- Further inquiry into methods of increasing and maintaining canopy cover in commercial areas and streetscapes adjacent to commercial areas as a spatial area of interest;
- Interrelationships between canopy cover and socio-economic data – such as social vulnerability, SEIFA, affluence or property prices;
- The impact that increasing hard surfaces will have on hydrological processes;
- Canopy cover, social vulnerability and heat vulnerability;
- Canopy cover tree species and age composition and the implications for canopy cover biological ecosystem services;
- Primary and secondary functions of canopy cover by place;
- Useful life expectancy of publicly owned trees (streetscapes and public space) and the implications for canopy cover growth rates; and
- Repeat monitoring of canopy cover and changes in cover class every census year.

7. CONCLUSIONS

Between 2011 and 2016 Maroondah had a stable and relatively high urban tree canopy cover with no statistically significant growth or loss over the five year period. The stable tree canopy cover percentage however, was accompanied by significant increases to hard surfaces in private land across the LGA and significant decrease to grass/ bare earth. These changes suggest that in many respects Maroondah's tree canopy cover protection policies are working simply because canopy cover did not significantly decline regardless of the large landscape changes happening in the LGA.

Land use tenure was an important factor in canopy cover distribution and change in Maroondah however, the most dramatic differences in canopy cover and canopy cover growth were observed between the aggregated spatial areas: AGA'VPO', AGA'DDO', AGA'SLO' and AGA'Other'. AGA'VPO' made a considerable positive impact on canopy cover for Maroondah and canopy cover in AGA'DDO' experienced a net significant loss over the same period. Further assessment into canopy cover growth and loss in AGA'DDO' indicated that while this aggregate area had higher than average construction activity the significant net loss in canopy cover was not due to unusually high canopy cover loss, as other areas that experienced net growth in canopy cover had the same level of canopy cover loss (such as AGA'VPO'). The important factor in the net canopy cover loss in AGA'DDO' appears to be that, over the five year period analysed, canopy cover growth was not able to compensate for canopy cover loss and this could be from a variety of factors such as tree age and morbidity or tree planting lags.

The greatest potential for tree planting projects on streetscape nature strips is in the 'SLO' and 'Other' aggregate spatial areas, with most (150 ha) of the potentially plantable land for street trees located in AGA'SLO'. However AGA'Other' which supports the lowest street tree canopy cover (12.3%) and higher plantable area (18.2% grass/bare earth) also has much potential to improve canopy cover.

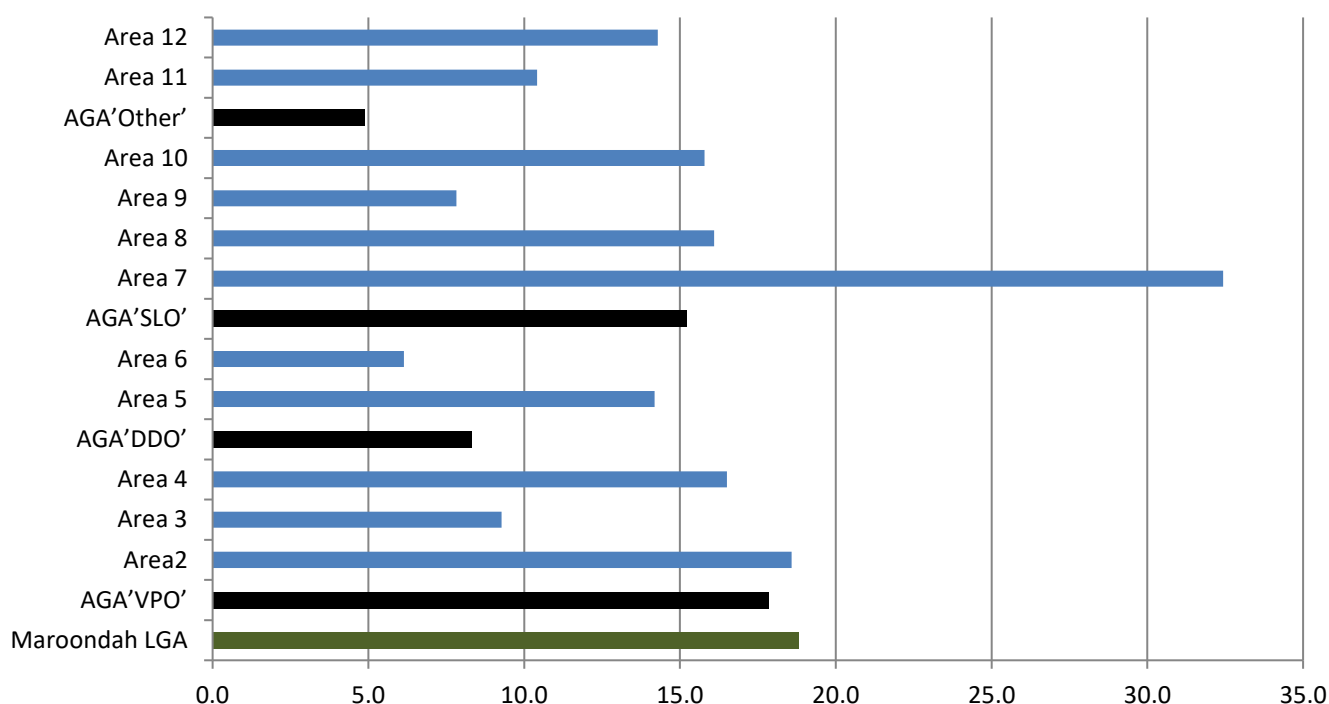
One of the most consistent and significant findings in this research was the increase in hard surfaces and the decrease in grass/ bare earth and shrubs. This suggests that the intensity of land use in Maroondah is moving towards the provision of constructed environments and tree centered ecosystem services primarily at the expense of lawns, garden areas and open land.

8. DATA QUALITY, INTREPRETATION AND COMPARISON

Parallax

Vegetation height, coupled with the angle that the image was taken can potentially lead to image parallax errors where tall objects appear to lean and 'move' the point between the two time images (Nowak & Greenfield 2012). In this study there was careful reassessment of all points where a canopy point was classified as Tree in 2011 but Not Tree in 2016. If there was a potential that parallax was the cause for the shift in category, the indicator was flagged. All areas had image parallax, ranging from 5% of tree loss for the Other category to 32% for the relatively small Area 6 (SLO). Further assessment of parallax indicates that it was a particular issue for tall street trees, as the angle of the image on a tall object can make a large impact on the 'leaning' of the tree and move the 'point'.

Figure 8.1 Percentage of points classified as canopy loss identified as parallax between images, 2011-16



Parallax is an indicator of image consistency between the two time points, thus images with high parallax may also have inflated canopy growth or loss in the sample. Due to the way that the central limit theorem functions with such a large number of points (2000), the results of parallax between the two times for total net change should not affect the mean estimate for canopy cover at one time point. However, the method used for comparison between the time points (McNemar test, cause of change) requires a dependent sampling regime, thus scores of high parallax between 2011 and 2016, for example those identified in Area 7, should be taken into consideration when ascertaining the cause of change between the time points.

Interpretation of the data

The percentages presented in this report are mean sample statistics via a simple random sample algorithm. A simple random sample means that hypothetically every point within the discrete area (geography) has an equal chance of being selected. Through the central limit theorem, a high enough sample size and (assumed) low non-sampling error we can be confident that the sample derived statistic mean will equate to the actual 'true' mean within the parameters of the standard error (se). However, when comparing the two samples between the two time points significance tests (p) should be adhered to. If $p > 0.05$ then we cannot be sure with 95% confidence that change has occurred in canopy cover over the time period. Similarly, the samples in this research are only an estimate for change between two time points, thus a high or low mean change in net canopy cover may be a reasonably constant trend happening over many years or it may be driven by multiple small events or one large event (such as greenfield development) over a short period of time.

Cover class and canopy cover

Canopy cover is an important policy and scientific indicator. However, it is important to note that canopy cover is just a two dimensional metric indicating the spread of canopy across an area and does not provide an indication of the composition, structure, diversity or the vertical extent of the urban tree canopy (McPherson et al. 2011). Canopy cover coding will result in the method also understating the other cover class categories (shrub, grass, hard). Thus a sample point on a tree that grows over pavements/buildings/undergrowth etc. will only be recognised as canopy cover producing a result which will underestimate the presence of shrub, grass/earth and hard cover. For example a property with 40% hard cover and a large tree with a canopy overhanging the driveway or dwelling may report a hard cover of only 35% as the tree's canopy overlaps 5% of the hardcover.

Hard cover and impervious surface

The hard cover variable is primarily produced as an indicator to classify an area where a tree planting cannot occur, thus a factor in the coding of the variable is that sample points on water bodies are classified as hard surface. This coding technique can interfere with using the hard surface indicator for other comparative purposes such as measuring impervious surfaces, which is an important indicator for measuring housing development, UHI or hydrology. To assess the scope of this issue a subset of sampled points was examined to assess the impact that coding water may have on the hard cover variable and it was found that less than 2% of the variable for most areas was classified as water in Maroondah LGA.

Canopy species composition

Experimental secondary analysis of sample points on canopy was done to assess the species composition of canopy trees (native/exotic). While for many assessed points the confidence in species categorisation was high, there were

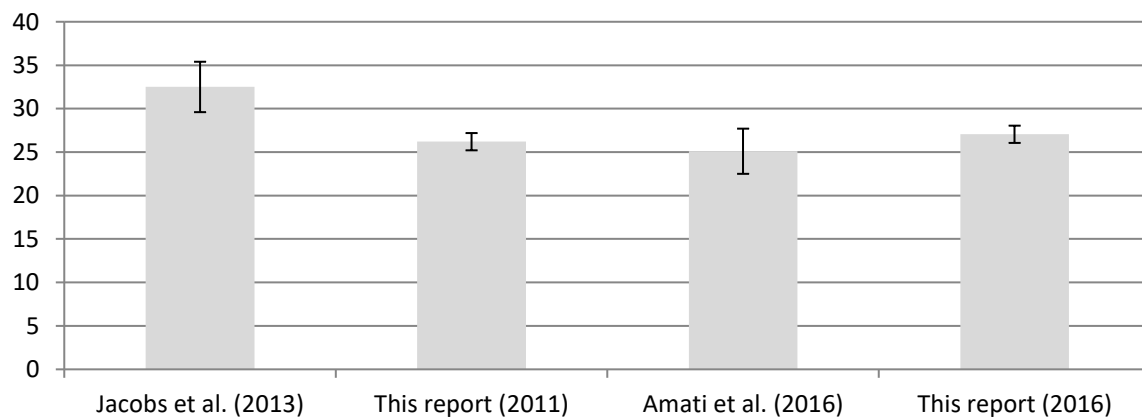
some 'edge' cases (~10%) and therefore an unknown level of non sampling error will be a factor in the final statistic and the data should be treated as indicative and not precise.

Comparisons with other research

Comparison between Amati et al. (2017) and this report align within the standard error for both results: Maroondah LGA 25.1%, (± 2.6) compared to 27.1% (± 1.0). This report used a much higher sample size (2000 vs. 1000) and also used the same criteria for tree canopy cover i.e. Three metre height by cover classes and high quality images were used for the assessment of results.

The differences between Jacobs et al. (2014) and this report however, are larger than the standard error, 32.5% (± 2.8) compared to 27.1% (± 1.0) and different at the lower and upper end of the standard error by 1.6% in canopy cover. The differences in results can be attributed primarily due image quality and sample size. In this report, higher quality images and a larger sample size were used for the assessment of sample points compared to the Jacobs et al (2014). For example Jacobs et al (2014) used 100 sample points and Google Earth satellite data was used to assess images hence non sampling error may be a factor in the 1.6% difference between canopy cover results.

Figure 8.2. Comparisons of canopy cover and year with Amati et al. (2017) and Jacobs et al. (2014)



9. SUPPLEMENTARY DETAILED TABLES

Table 9.1. Cover estimates for each aggregated spatial area of Maroondah by land-use: 2011, %

Aggregate Spatial Area	Tenure	Tree Cover		Shrub Cover		Grass/ Bare Ground		Hard Surface	
		%	se	%	se	%	se	%	se
Maroondah LGA									
	Street	24.9	2.3	2.5	0.8	16.7	2.0	55.8	2.6
	Private	25.0	1.1	9.1	0.8	23.8	1.1	42.1	1.3
	Public	35.9	3.3	5.1	1.5	41.0	3.3	18.0	2.6
	Total	26.2	1.0	7.5	0.6	24.4	1.0	41.9	1.1
'VPO'									
	Street	25.2	3.7	7.4	2.3	24.4	3.7	43.0	4.3
	Private	39.8	1.5	6.1	0.7	43.4	1.5	10.7	0.9
	Public	46.1	1.8	6.2	0.9	39.9	1.8	7.9	1.0
	Total	41.2	1.1	6.2	0.5	40.8	1.1	11.9	0.7
'DDO'									
	Street	33.8	2.6	6.9	1.4	18.4	2.2	40.9	2.7
	Private	34.7	1.2	15.4	0.9	16.8	0.9	33.1	1.1
	Public	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Total	34.6	1.1	14.1	0.8	17.1	0.8	34.3	1.1
'SLO'									
	Street	25.8	2.1	3.9	0.9	21.2	2.0	49.2	2.5
	Private	20.6	1.1	12.2	0.9	24.6	1.1	42.6	1.3
	Public	31.5	3.8	2.7	1.3	43.0	4.1	22.8	3.4
	Total	22.5	0.9	9.7	0.7	25.3	1.0	42.5	1.1
'Other'									
	Street	11.2	1.8	3.5	1.0	18.5	2.2	66.8	2.7
	Private	7.2	0.7	6.8	0.7	22.8	1.1	63.2	1.3
	Public	19.4	2.5	4.7	1.3	58.1	3.1	17.8	2.4
	Total	9.4	0.7	6.1	0.5	26.6	1.0	58.0	1.1

Table 9.2. Cover estimates for each aggregated spatial area of Maroondah by land-use: 2016, %

Aggregate Spatial Area	Tenure	Tree Cover		Shrub Cover		Grass/ Bare Ground		Hard Surface	
		%	se	%	se	%	se	%	se
Maroondah LGA									
	Street	25.2	2.3	1.7	0.7	15.6	1.9	57.5	2.6
	Private	25.9	1.2	7.9	0.7	22.0	1.1	44.2	1.3
	Public	37.3	3.3	5.1	1.5	38.7	3.3	18.9	2.7
	Total	27.1	1.0	6.5	0.6	22.7	0.9	43.8	1.1
'VPO'									
	Street	27.4	3.8	7.4	2.3	16.3	3.2	48.9	4.3
	Private	39.9	1.5	5.5	0.7	39.4	1.5	15.2	1.1
	Public	48.1	1.8	5.0	0.8	39.1	1.8	7.9	1.0
	Total	42.1	1.1	5.4	0.5	37.8	1.1	14.8	0.8
'DDO'									
	Street	32.2	2.6	5.9	1.3	19.4	2.2	42.5	2.8
	Private	32.7	1.1	13.8	0.8	17.2	0.9	36.3	1.2
	Public	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Total	32.7	1.0	12.6	0.7	17.5	0.8	37.3	1.1
'SLO'									
	Street	26.0	2.2	4.3	1.0	19.8	2.0	49.9	2.5
	Private	20.7	1.1	12.4	0.9	22.3	1.1	44.6	1.3
	Public	32.2	3.8	4.0	1.6	43.6	4.1	20.1	3.3
	Total	22.6	0.9	10.1	0.7	23.4	0.9	43.9	1.1
'Other'									
	Street	12.5	1.9	3.5	1.0	18.2	2.2	65.8	2.7
	Private	7.3	0.7	6.6	0.7	20.5	1.1	65.6	1.3
	Public	19.4	2.5	5.9	1.5	56.9	3.1	17.8	2.4
	Total	9.7	0.7	6.0	0.5	24.8	1.0	59.6	1.1

Table 9.3. Change in cover for each aggregated spatial area of Maroondah by land-use: 2011-2016

Aggregate Spatial Area	Tenure	Tree Cover		Shrub Cover		Grass/ Bare Ground		Hard Surface	
		%	<i>p</i>	%	<i>p</i>	%	<i>p</i>	%	<i>p</i>
Maroondah LGA									
	Street	0.3	1.00	-0.8	0.51	-1.1	0.57	1.7	0.26
	Private	0.9	0.31	-1.2	0.13	-1.8	0.03	2.1	0.00
	Public	1.4	0.61	0.0	1.00	-2.3	0.41	0.9	0.69
	Total	0.8	0.24	-1.0	0.10	-1.8	0.01	1.9	0.00
'VPO'									
	Street	2.2	0.55	0.0	0.34	-8.1	0.01	5.9	0.02
	Private	0.1	1.00	-0.6	0.70	-3.9	0.00	4.5	0.00
	Public	2.0	0.13	-1.2	0.36	-0.8	0.59	0.0	1.00
	Total	1.0	0.25	-0.8	0.20	-3.1	0.00	2.9	0.00
'DDO'									
	Street	-1.6	0.44	-0.9	0.34	0.9	0.66	1.6	0.36
	Private	-2.0	0.01	-1.6	0.70	0.4	0.69	3.2	0.00
	Public	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Total	-2.0	0.01	-1.5	0.20	0.4	0.55	3.0	0.00
'SLO'									
	Street	0.2	1.00	0.5	0.34	-1.4	0.88	0.7	0.75
	Private	0.1	1.00	0.2	0.70	-2.3	0.01	2.0	0.01
	Public	0.7	1.00	1.3	0.36	0.7	1.00	-2.7	0.13
	Total	0.1	0.88	0.3	0.20	-1.9	0.01	1.4	0.03
'Other'									
	Street	1.3	0.39	0.0	0.34	-0.3	1.00	-1.0	0.58
	Private	0.1	0.90	-0.3	0.70	-2.3	0.00	2.4	0.00
	Public	0.0	1.00	1.2	0.36	-1.2	0.65	0.0	1.00
	Total	0.3	0.6	0.0	0.2	-1.9	0.00	1.6	0.00

Table 9.4. Species composition (native/exotic) of the canopy cover of Maroondah by spatial area, 2016

Aggregate Spatial Area	Spatial Area	Spatial Area description	Native	Exotic
LGA	Area1	Maroondah LGA	59.5	40.5
VPO			85.4	13.9
	Area2	VPO1 overlap with DDO1	83.9	16.1
	Area 3	VPO1 overlap with DDO2	74.4	25.6
	Area 4	VPO1 no overlap with DDO1 or DDO2	86.9	13.1
DDO			52.5	47.5
	Area 5	DDO1 no overlap with VPO1	55.5	44.5
	Area 6	DDO2 no overlap with VPO1	52.3	47.7
SLO			53.6	46.4
	Area 7	SLO1 no overlap with VPO1 DDO1 DDO2	71.2	28.8
	Area 8	SLO2 no overlap with VPO1 DDO1 DDO2	69.6	30.4
	Area 9	SLO3 no overlap with VPO1 DDO1 DDO2	52.5	47.5
	Area 10	SLO4 no overlap with VPO1 DDO1 DDO2	50.3	49.7
Other			67.9	32.1
	Area 11	Local Law no overlap with VPO1 DDO1 DDO2 SLO1-4	65.0	35.0
	Area 12	No Controls	61.1	38.9

Table 9.5. Cover estimates for each spatial area of Maroondah by land-use: 2011, %

Spatial Area	Tenure	Tree Cover		Shrub Cover		Grass/ Bare Ground		Hard Surface	
		%	se	%	se	%	se	%	se
Area 1: Maroondah LGA									
	Street	24.9	2.3	2.5	0.8	16.7	2.0	55.8	2.6
	Private	25.0	1.1	9.1	0.8	23.8	1.1	42.1	1.3
	Public	35.9	3.3	5.1	1.5	41.0	3.3	18.0	2.6
	Total	26.2	1.0	7.5	0.6	24.4	1.0	41.9	1.1
Area 2: VPO1 overlap with DDO1									
	Street	47.7	3.2	11.3	2.0	16.7	2.4	24.3	2.8
	Private	51.2	1.2	8.3	0.7	21.7	1.0	18.8	1.0
	Public	46.8	5.6	11.4	3.6	22.8	4.7	19.0	4.4
	Total	50.6	1.1	8.8	0.6	21.2	0.9	19.5	0.9
Area 3: VPO1 overlap with DDO2									
	Street	43.4	4.0	11.8	2.6	18.4	3.1	26.3	3.6
	Private	47.6	1.2	10.8	0.7	22.3	1.0	19.3	0.9
	Public	55.6	7.4	2.2	2.2	42.2	7.4	0.0	0.0
	Total	47.5	1.1	10.7	0.7	22.5	0.9	19.4	0.9
Area 4: VPO1 no overlap with DDO1 or DDO2									
	Street	14.3	3.3	7.1	2.4	32.1	4.4	46.4	4.7
	Private	33.1	1.5	6.0	0.7	50.1	1.6	10.8	1.0
	Public	44.9	1.7	6.2	0.8	40.4	1.7	8.6	0.9
	Total	37.2	1.1	6.2	0.5	44.9	1.1	11.8	0.7
Area 5: DDO1 no overlap with VPO1									
	Street	41.7	2.6	6.9	1.4	13.4	1.8	38.0	2.6
	Private	44.8	1.2	9.9	0.7	19.8	1.0	25.5	1.1
	Public	94.1	5.7	5.9	5.7	0.0	0.0	0.0	0.0
	Total	44.7	1.1	9.4	0.7	18.6	0.9	27.5	1.0
Area 6: DDO2 no overlap with VPO1									
	Street	31.9	2.6	7.1	1.4	18.9	2.2	42.1	2.7
	Private	33.2	1.2	16.0	0.9	17.3	0.9	33.6	1.2
	Public	0.0	0.0	50.0	35.4	0.0	0.0	50.0	35.4
	Total	33.0	1.1	14.6	0.8	17.5	0.8	35.0	1.1
Area 7: SLO1 no overlap with VPO1 DDO1 DDO2									
	Street	13.3	3.4	4.1	2.0	54.1	5.0	28.6	4.6
	Private	16.8	0.9	7.8	0.6	64.4	1.1	10.9	0.7
	Public	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total	16.7	0.8	7.7	0.6	63.9	1.1	11.8	0.7
Area 8: SLO2 no overlap with VPO1 DDO1 DDO2									
	Street	35.9	2.5	5.4	1.2	18.8	2.0	39.9	2.6
	Private	37.4	1.4	6.7	0.7	34.5	1.4	21.3	1.2
	Public	22.6	1.9	1.4	0.5	74.1	2.0	1.8	0.6
	Total	33.5	1.1	5.2	0.5	41.4	1.1	20.0	0.9
Area 9: SLO3 no overlap with VPO1 DDO1 DDO2									
	Street	22.3	2.2	4.2	1.1	17.8	2.0	55.7	2.6
	Private	23.9	1.1	14.1	0.9	20.9	1.1	41.1	1.3
	Public	43.4	3.7	3.4	1.4	34.9	3.6	18.3	2.9
	Total	25.4	1.0	11.4	0.7	21.6	0.9	41.7	1.1
Area 10: SLO4 no overlap with VPO1 DDO1 DDO2									
	Street	24.8	2.1	3.7	0.9	22.7	2.0	48.7	2.4
	Private	19.7	1.1	11.5	0.8	22.7	1.1	46.1	1.3
	Public	26.3	3.5	5.0	1.7	45.6	3.9	23.1	3.3
	Total	21.4	0.9	9.3	0.6	24.6	1.0	44.8	1.1
Area 11: Local Law no overlap									
	Street	15.2	2.1	2.8	1.0	18.7	2.3	63.3	2.9
	Private	8.6	0.7	7.6	0.7	24.7	1.1	59.1	1.3
	Public	17.7	2.3	2.3	0.9	62.8	3.0	17.3	2.3
	Total	10.8	0.7	6.3	0.5	28.9	1.0	54.1	1.1
Area 12: No Controls									
	Street	7.3	1.4	6.4	1.3	23.5	2.2	62.7	2.6
	Private	7.6	0.7	6.3	0.7	19.7	1.1	66.5	1.3
	Public	16.7	2.3	5.4	1.4	64.6	3.0	13.2	2.1
	Total	8.7	0.6	6.2	0.5	26.2	1.0	59.0	1.1

Table 9.6. Cover estimates for each spatial area of Maroondah by land-use: 2016, %

Spatial Area	Tenure	Tree Cover		Shrub Cover		Grass/ Bare Ground		Hard Surface	
		%	se	%	se	%	se	%	se
Area 1: Maroondah LGA									
	Street	25.2	2.3	1.7	0.7	15.6	1.9	57.5	2.6
	Private	25.9	1.2	7.9	0.7	22.0	1.1	44.2	1.3
	Public	37.3	3.3	5.1	1.5	38.7	3.3	18.9	2.7
	Total	27.1	1.0	6.5	0.6	22.7	0.9	43.8	1.1
Area 2: VPO1 overlap with DDO1									
	Street	52.3	3.2	7.1	1.7	13.4	2.2	27.2	2.9
	Private	57.6	1.2	5.3	0.5	17.1	0.9	20.1	1.0
	Public	53.2	5.6	6.3	2.7	22.8	4.7	17.7	4.3
	Total	56.8	1.1	5.6	0.5	16.9	0.8	20.9	0.9
Area 3: VPO1 overlap with DDO2									
	Street	50.7	4.1	3.9	1.6	19.7	3.2	25.7	3.5
	Private	54.4	1.2	6.9	0.6	18.6	0.9	20.1	0.9
	Public	60.0	7.3	2.2	2.2	37.8	7.2	0.0	0.0
	Total	54.2	1.1	6.6	0.6	19.2	0.9	20.1	0.9
Area 4: VPO1 no overlap with DDO1 or DDO2									
	Street	16.1	3.5	7.1	2.4	19.6	3.8	57.1	4.7
	Private	32.2	1.5	5.4	0.7	47.4	1.6	14.9	1.1
	Public	46.8	1.7	5.0	0.7	39.4	1.7	8.8	1.0
	Total	37.7	1.1	5.4	0.5	42.4	1.1	14.6	0.8
Area 5: DDO1 no overlap with VPO1									
	Street	45.1	2.7	5.7	1.2	12.0	1.7	37.1	2.6
	Private	43.2	1.2	10.0	0.7	18.9	1.0	27.9	1.1
	Public	94.1	5.7	5.9	5.7	0.0	0.0	0.0	0.0
	Total	44.0	1.1	9.3	0.6	17.5	0.8	29.3	1.0
Area 6: DDO2 no overlap with VPO1									
	Street	30.3	2.6	6.5	1.4	19.2	2.2	44.0	2.8
	Private	31.2	1.1	14.6	0.9	17.3	0.9	36.9	1.2
	Public	0.0	0.0	50.0	35.4	0.0	0.0	50.0	35.4
	Total	31.0	1.0	13.4	0.8	17.6	0.9	38.1	1.1
Area 7: SLO1 no overlap with VPO1 DDO1 DDO2									
	Street	14.3	3.5	6.1	2.4	54.1	5.0	25.5	4.4
	Private	19.0	0.9	8.4	0.6	59.9	1.1	12.7	0.8
	Public	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total	18.8	0.9	8.3	0.6	59.6	1.1	13.4	0.8
Area 8: SLO2 no overlap with VPO1 DDO1 DDO2									
	Street	37.5	2.5	3.5	1.0	17.7	2.0	41.3	2.6
	Private	36.4	1.4	5.4	0.7	35.4	1.4	22.8	1.2
	Public	21.2	1.8	0.4	0.3	76.8	1.9	1.6	0.6
	Total	32.9	1.1	3.9	0.4	42.3	1.1	21.0	0.9
Area 9: SLO3 no overlap with VPO1 DDO1 DDO2									
	Street	21.7	2.2	5.0	1.2	15.6	1.9	57.7	2.6
	Private	22.3	1.1	13.4	0.9	20.2	1.0	44.1	1.3
	Public	42.9	3.7	3.4	1.4	36.6	3.6	17.1	2.8
	Total	24.0	1.0	11.1	0.7	20.8	0.9	44.2	1.1
Area 10: SLO4 no overlap with VPO1 DDO1 DDO2									
	Street	27.2	2.2	4.7	1.0	19.9	1.9	48.2	2.4
	Private	19.1	1.0	12.1	0.9	21.0	1.1	47.8	1.3
	Public	28.1	3.6	3.8	1.5	46.9	3.9	21.3	3.2
	Total	21.6	0.9	9.9	0.7	22.9	0.9	45.8	1.1
Area 11: Local Law no overlap									
	Street	17.7	2.3	2.5	0.9	18.0	2.3	61.8	2.9
	Private	9.3	0.8	6.8	0.7	21.7	1.1	62.2	1.3
	Public	20.7	2.5	3.0	1.0	58.3	3.0	18.0	2.4
	Total	12.0	0.7	5.7	0.5	26.1	1.0	56.3	1.1
Area 12: No Controls									
	Street	8.7	1.5	7.8	1.4	21.6	2.2	61.9	2.6
	Private	7.1	0.7	6.6	0.7	18.0	1.0	68.3	1.2
	Public	14.8	2.2	7.0	1.6	64.6	3.0	13.6	2.1
	Total	8.4	0.6	6.9	0.6	24.7	1.0	60.2	1.1

Table 9.7. Change in cover for each spatial area of Maroondah by land-use: 2011-2016

Spatial Area	Tenure	Tree Cover		Shrub Cover		Grass/ Bare Ground		Hard Surface	
		%	p	%	p	%	p	%	p
Area 1: Maroondah LGA									
	Street	0.3	1.00	-0.8	0.51	-1.1	0.57	1.7	0.26
	Private	0.9	0.31	-1.2	0.13	-1.8	0.03	2.1	0.00
	Public	1.4	0.61	0.0	1.00	-2.3	0.41	0.9	0.69
	Total	0.8	0.24	-1.0	0.10	-1.8	0.01	1.9	0.00
Area 2: VPO1 overlap with DDO1									
	Street	4.6	0.09	-4.2	0.04	-3.3	0.12	2.9	0.09
	Private	6.4	0.00	-3.0	0.00	-4.6	0.00	1.2	0.04
	Public	6.3	0.23	-5.1	0.22	0.0	1.00	-1.3	1.00
	Total	6.2	0.00	-3.2	0.00	-4.3	0.00	1.4	0.01
Area 3: VPO1 overlap with DDO2									
	Street	7.2	0.04	-7.9	0.04	1.3	0.80	-0.7	1.00
	Private	6.8	0.00	-3.9	0.00	-3.7	0.00	0.8	0.19
	Public	4.4	0.69	0.0	0.22	-4.4	0.69	0.0	n/a
	Total	6.8	0.00	-4.1	0.00	-3.3	0.00	0.6	0.25
Area 4: VPO1 no overlap with DDO1 or DDO2									
	Street	1.8	0.69	0.0	0.04	-12.5	0.00	10.7	0.00
	Private	-0.9	0.46	-0.6	0.00	-2.7	0.03	4.2	0.00
	Public	1.9	0.11	-1.1	0.22	-1.0	0.43	0.2	0.82
	Total	0.5	0.54	-0.8	0.00	-2.5	0.00	2.8	0.00
Area 5: DDO1 no overlap with VPO1									
	Street	3.4	0.11	-1.1	0.42	-1.4	0.38	-0.9	0.73
	Private	-1.6	0.10	0.1	0.93	-1.0	0.38	2.4	0.00
	Public	0.0	n/a	0.0	n/a	0.0	n/a	0.0	n/a
	Total	-0.7	0.43	-0.1	0.93	-1.1	0.17	1.8	0.00
Area 6: DDO2 no overlap with VPO1									
	Street	-1.5	0.42	-0.6	0.80	0.3	1.00	1.9	0.21
	Private	-2.0	0.01	-1.4	0.07	0.1	1.00	3.3	0.00
	Public	0.0	n/a	0.0	n/a	0.0	n/a	0.0	n/a
	Total	-2.0	0.01	-1.3	0.06	0.1	0.94	3.1	0.00
Area 7: SLO1 no overlap with VPO1 DDO1 DDO2									
	Street	1.0	1.00	2.0	0.63	0.0	1.00	-3.1	0.25
	Private	2.2	0.00	0.6	0.34	-4.5	0.00	1.8	0.00
	Public	0.0	n/a	0.0	n/a	0.0	n/a	0.0	n/a
	Total	2.1	0.00	0.7	0.26	-4.3	0.00	1.6	0.00
Area 8: SLO2 no overlap with VPO1 DDO1 DDO2									
	Street	1.6	0.48	-1.9	0.02	-1.1	0.50	1.4	0.49
	Private	-1.1	0.30	-1.3	0.01	0.9	0.37	1.5	0.00
	Public	-1.4	0.17	-1.0	0.13	2.6	0.02	-0.2	1.00
	Total	-0.6	0.37	-1.4	0.00	1.0	0.14	1.1	0.01
Area 9: SLO3 no overlap with VPO1 DDO1 DDO2									
	Street	-0.6	0.88	0.8	0.61	-2.2	0.15	1.9	0.34
	Private	-1.6	0.06	-0.6	0.47	-0.8	0.46	3.0	0.00
	Public	-0.6	1.00	0.0	1.00	1.7	0.58	-1.1	0.63
	Total	-1.4	0.07	-0.3	0.68	-0.8	0.31	2.5	0.00
Area 10: SLO4 no overlap with VPO1 DDO1 DDO2									
	Street	2.3	0.18	0.9	0.34	-2.8	0.02	-0.5	0.86
	Private	-0.6	0.43	0.6	0.48	-1.7	0.07	1.7	0.03
	Public	1.9	0.45	-1.3	0.63	1.3	0.69	-1.9	0.25
	Total	0.2	0.81	0.5	0.40	-1.7	0.02	0.9	0.13
Area 11: Local Law no overlap									
	Street	2.5	0.14	-0.4	0.73	-0.7	0.82	-1.4	0.39
	Private	0.7	0.34	-0.9	0.19	-3.0	0.00	3.2	0.00
	Public	3.0	0.08	0.8	1.00	-4.5	0.02	0.8	0.69
	Total	1.3	0.03	-0.6	0.27	-2.9	0.00	2.2	0.00
Area 12: No Controls									
	Street	1.4	0.30	1.4	0.34	-2.0	0.21	-0.8	0.65
	Private	-0.5	0.41	0.3	0.70	-1.7	0.01	1.9	0.01
	Public	-1.9	0.18	1.6	0.36	0.0	1.00	0.4	1.00
	Total	-0.4	0.49	0.7	0.20	-1.5	0.01	1.2	0.02

10. SUPPLEMENTARY MAPS

Figure 10.1. *Tree canopy cover 2011 & 2016*

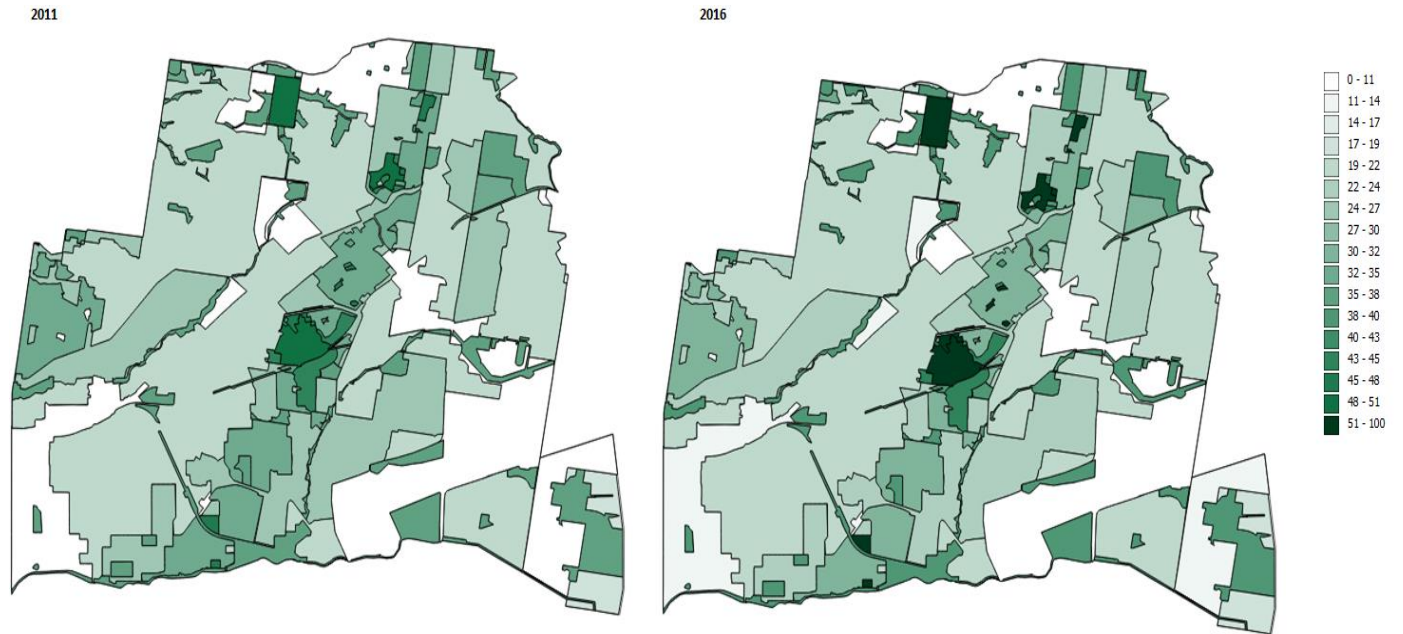


Figure 10.2. *Shrub cover 2011 & 2016*

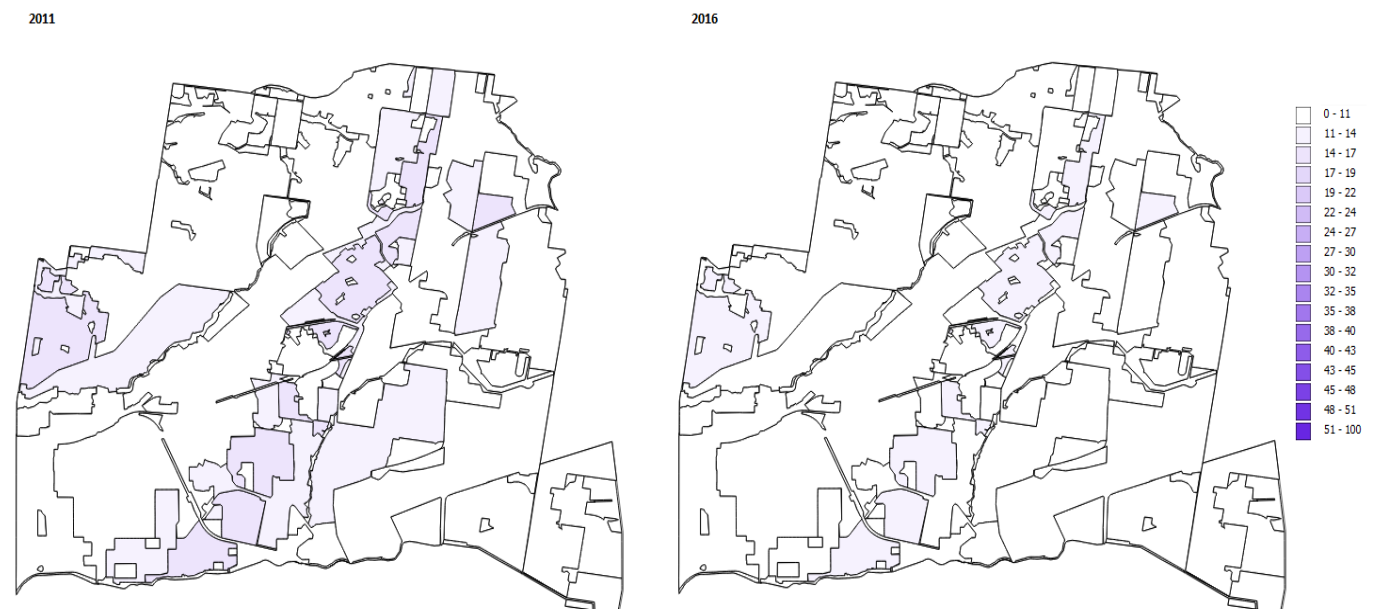
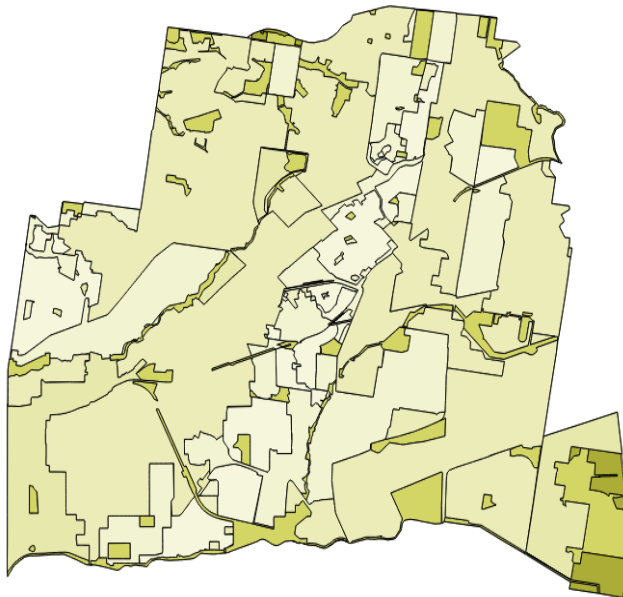


Figure 10.3. Grass/bare earth cover 2011 & 2016

2011



2016

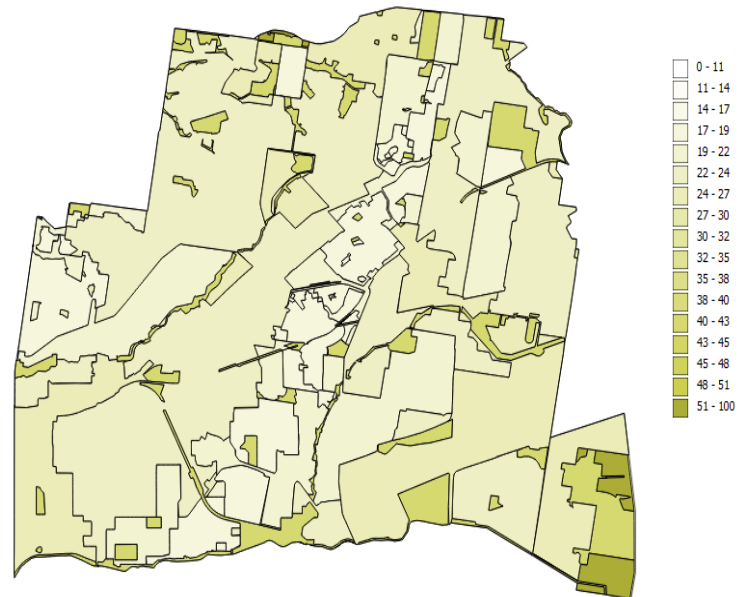


Figure 10.4. Hard cover 2011 & 2016

2011



2016

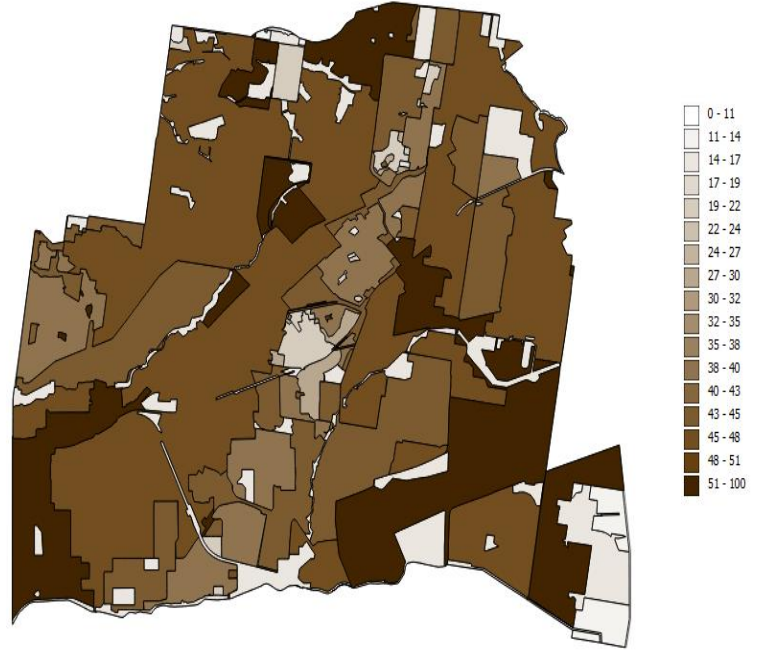


Figure 10.5. *Change in tree cover between 2011-2016*

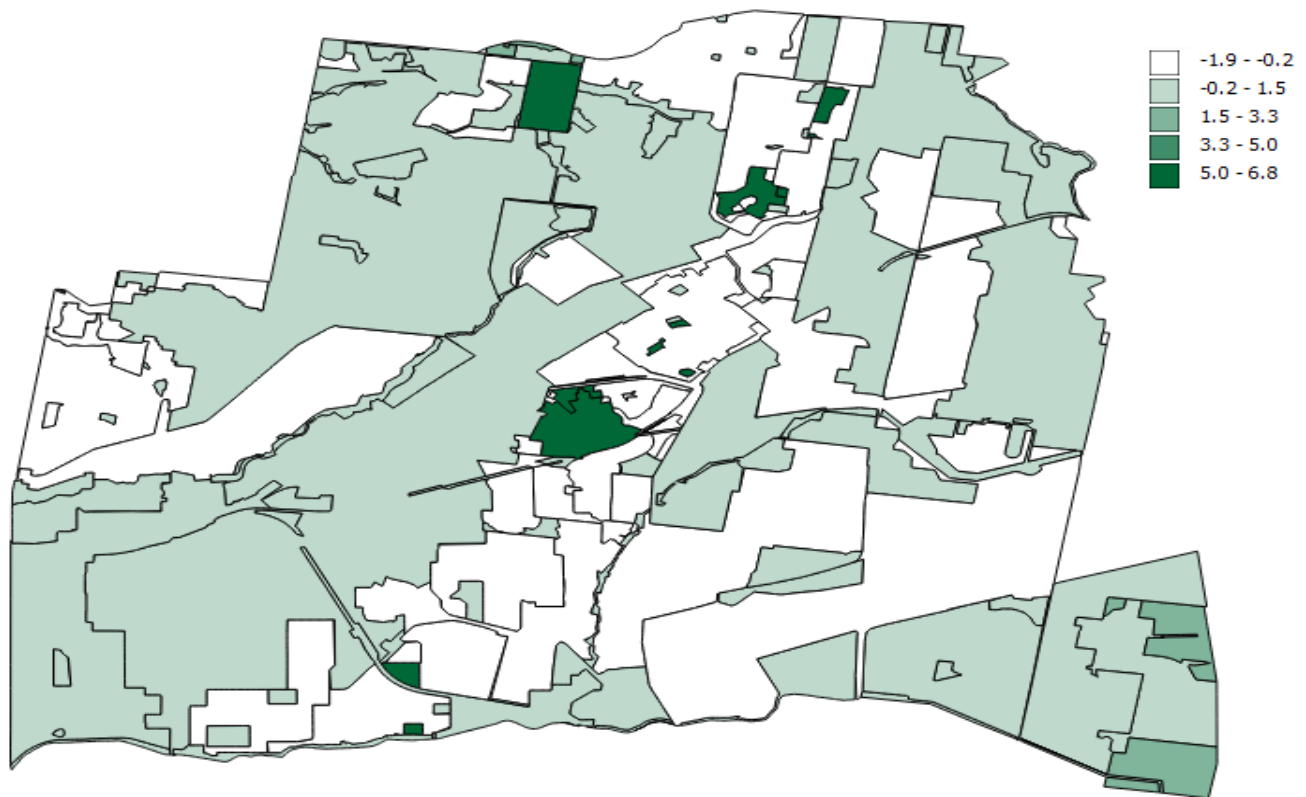


Figure 10.6. *Change in shrub cover between 2011-2016*

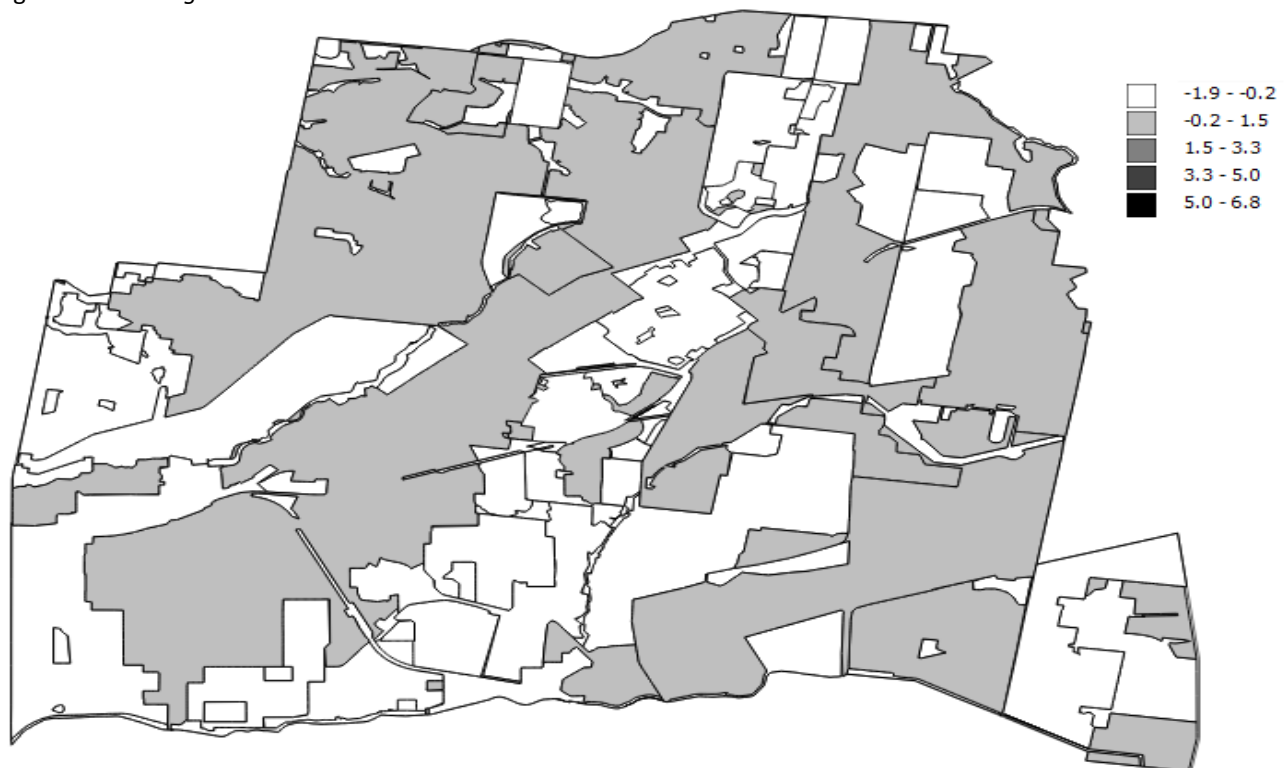


Figure 10.7. *Change in grass cover between 2011-2016*

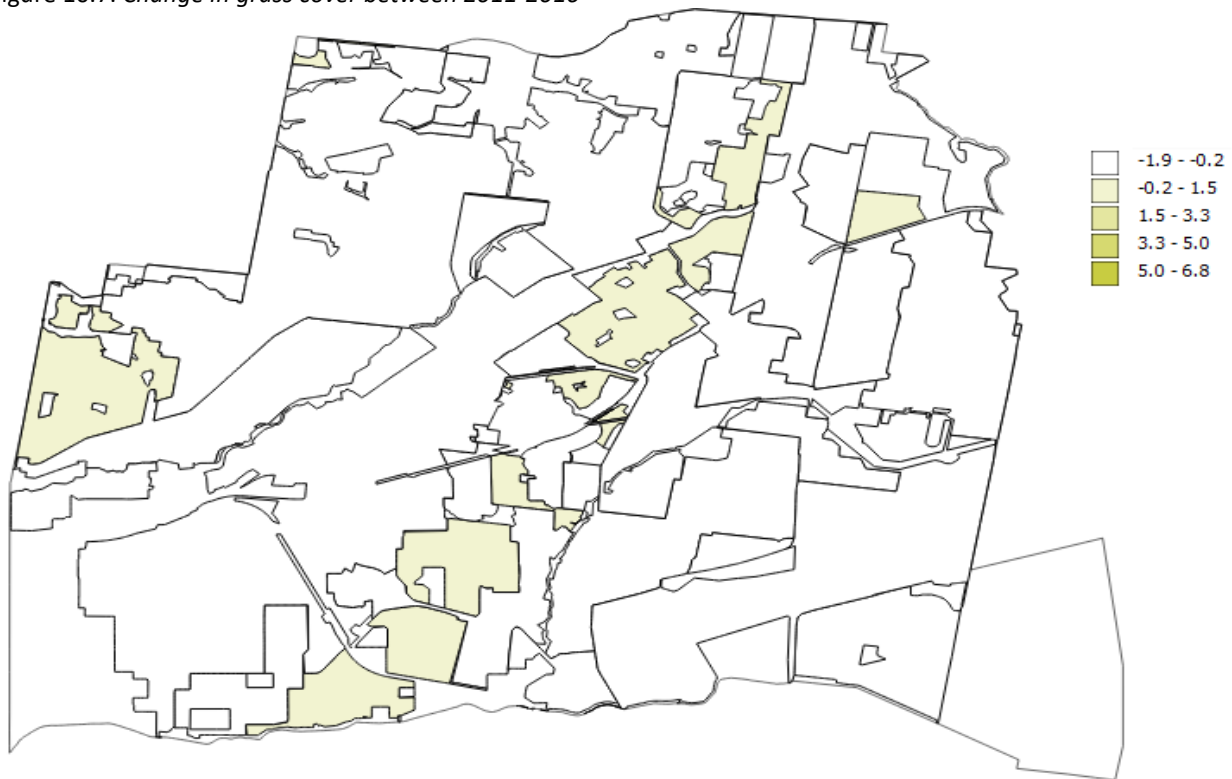
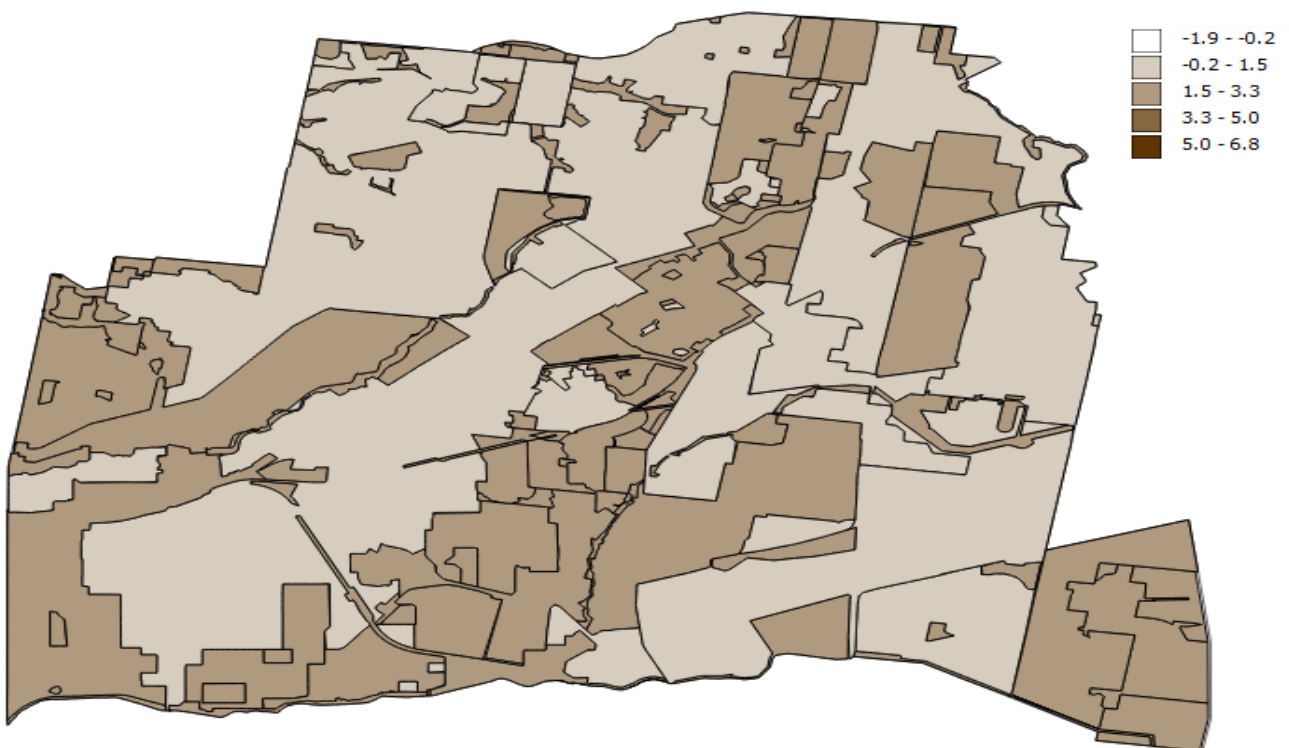


Figure 10.8. *Change in hard cover between 2011-2016*



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