# Wyndham Canopy & Landscape Analysis, 2007 to 2017

Joseph Kaspar
Greenspace Consultant
July, 2019

**CONTENTS**


1. SUMMARY…………………………………………………………………………………………………………..4
2. INTRODUCTION………………………………………………………………………………………………5
3. BACKGROUND……………………………………………………………………………………………….....5
4. METHODOLOGY………………………………………………………………………………………………6
5. OUTCOMES…………………………………………………………………………………………………….11
6. EVALUATION AND DISCUSSION……………………………………………………………………...15
7. CONCLUSION…………………………………………………………………………………………………19
8. DATA QUALITY, INTERPRETATION AND COMPARISONS……………………………………….20
9. SUPPLEMENTARY DETAILED TABLES…………………………………………………………………22
10. REFERENCES…………………………………………………………………………………………………23

## 1. SUMMARY

This research report was commissioned by Wyndham City Council to undertake an analysis of Wyndham's canopy and landscape characteristics and provide insight into the dynamic indicators that impact on tree canopy cover. The research is an important step to benchmarking Wyndham's urban forest by providing a snapshot of Wyndham's canopy cover in 2007 and 2017 as well as an estimate of the magnitude of change in canopy cover over the ten year period. The findings from this research will facilitate Wyndham City Council's ability to develop the upcoming 'Tree and Urban Forest Policy' so that Wyndham City Council can implement proactive and evidence-based urban forest management strategies into the future.

Results from the research indicate that Wyndham has a low canopy cover (3.6%, ±0.4%) compared to other Councils in the Melbourne region however, in the period between 2007 and 2017, Wyndham's tree canopy cover grew by a significant amount (+1.2%, $p<0.01$). This change in tree canopy cover amounts to a relative increase of +51% over the ten year period. The high relative increase in tree canopy cover was accompanied by significant increases to hard surfaces in all the spatial areas assessed and a significant decrease in grass or bare earth surface area. The increase in canopy cover was also uniquely accompanied by very low canopy cover 'churn' which indicates that the existing stock of canopy trees are not being cleared in significant numbers. This low loss of exiting tree stock also corresponded with significant growth in existing trees and new tree planting over the ten year period. In Public Urban Wyndham Area for example, up to 47% of the canopy cover growth came from new greenfield tree plantings within the ten year period. Land-use was correspondingly an important factor in canopy cover distribution and change in Wyndham, with Public Urban Area having the highest canopy cover (7.9%, ±0.6%) and the highest growth in canopy cover (+2.2%).

One of the most consistent and significant findings of this research was that the increase in hard surfaces and canopy cover also corresponded with a decrease in grass or bare earth. This suggests that the intensity of land-use in Wyndham is moving towards the provision of constructed environments and tree centered ecosystem services primarily at the expense of open grassland and farmland. Similarly, the significant landscape changes estimated in this report have been accompanied by significant population growth and housing development. Indeed, relative canopy cover growth in the Council tracks closely to population growth (51% compared to 52%). Since the 2016 census, Wyndham's population is projected to grow by 74.2% by 2036 to reach 435,832 people. In order for Wyndham to maintain canopy cover growth at similar rates, a similar level of tree protection, planting and planning will need to be implemented.

The patterns from this report suggest that the City of Wyndham's tree canopy cover protection and planting policies between 2007 and 2017 resulted in significant growth in tree canopy cover with extensive evidence of new tree plantings and few examples of loss in existing trees stocks. Significant and intensive tree planting and protection initiatives will need to be continued into the future if Wyndham is to match the ambitious canopy cover targets set out in Council's City Forest and Habitat Strategy, 2017.

## 2. INTRODUCTION

The purpose of this research is to estimate canopy cover for four spatial areas in Wyndham City Council. Additional outputs include to estimate change in canopy cover and cover class and to identify the primary cause of decline (construction/ removal) or increase (tree growth or tree planting) in tree canopy cover. The ultimate aim of the project is to provide data on canopy cover and canopy cover change in Wyndham to inform urban forest strategies into the future.

Specific outputs from this research include:

- Sample based canopy cover percentages for Wyndham and each spatial area assessed (4 in total) for 2007 and 2017;
- Estimates of change in canopy cover between 2007 and 2017;
- Identification of potential cause of canopy cover decrease, if any (construction/removal);
- Identification of potential cause of canopy cover increase, if any (tree growth/tree planting);
- Estimates of cover classes (hard, grass, shrub, tree) for each spatial area; 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 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 Wyndham 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; Tyrvainen & 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.

**Wyndham and tree canopy cover**

Wyndham City Council faces unique challenges in managing or increasing a healthy urban forest including difficult local environmental conditions (soil and low rainfall) accompanied by significant residential growth and development. This project will be an important step to benchmarking Wyndham's urban forest by providing a snapshot of Wyndham's canopy cover and an estimate of change over the ten year period between 2007 and 2017 with an aim to facilitate a proactive urban forest strategy into the future.

**Strategic alignment with Wyndham City Council vision**

*"Wyndham will be a well-connected place in terms of both physical infrastructure and technology, it will have a quality road network that is supported in its transportation task by alternative transport options such as walking, cycling and innovative public transport. Wyndham will be an attractive place where the built environment is designed to maximise its natural environmental assets and feature a growing tree canopy providing more shade and natural habitat."* - Wyndham Urban Framework Plan, May 2019

## 4. METHODOLOGY

The 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 Wyndham (4 spatial areas) for images from 2007 and 2017 (total of 16,000 sample points). 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). If change was recorded between 2007 and 2017 two additional assessments of the area was made to ascertain the cause of the decrease or cause of increase. 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**

The statistical boundaries used in the study were Wyndham LGA and 3 additional subset polygons sourced from Wyndham City Council (Wyndham Urban area, Urban Private, Urban public) (Table 4.1, Figures 4.1, 4.2).

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

| Spatial Areas | Spatial area description | Area Km$^2$ | % of Wyndham |
|---|---|---|---|
| **LGA** | **Wyndham LGA** | **542** | **100** |
| **Urban Area** | **Urban Wyndham Area** | **228** | **42.0** |
| Urban Private | Private Urban Wyndham | 184 | 34.0 |
| Urban Public | Public Urban Wyndham | 48 | 8.8 |

Figure 4.1. *Wyndham LGA and assessment area*

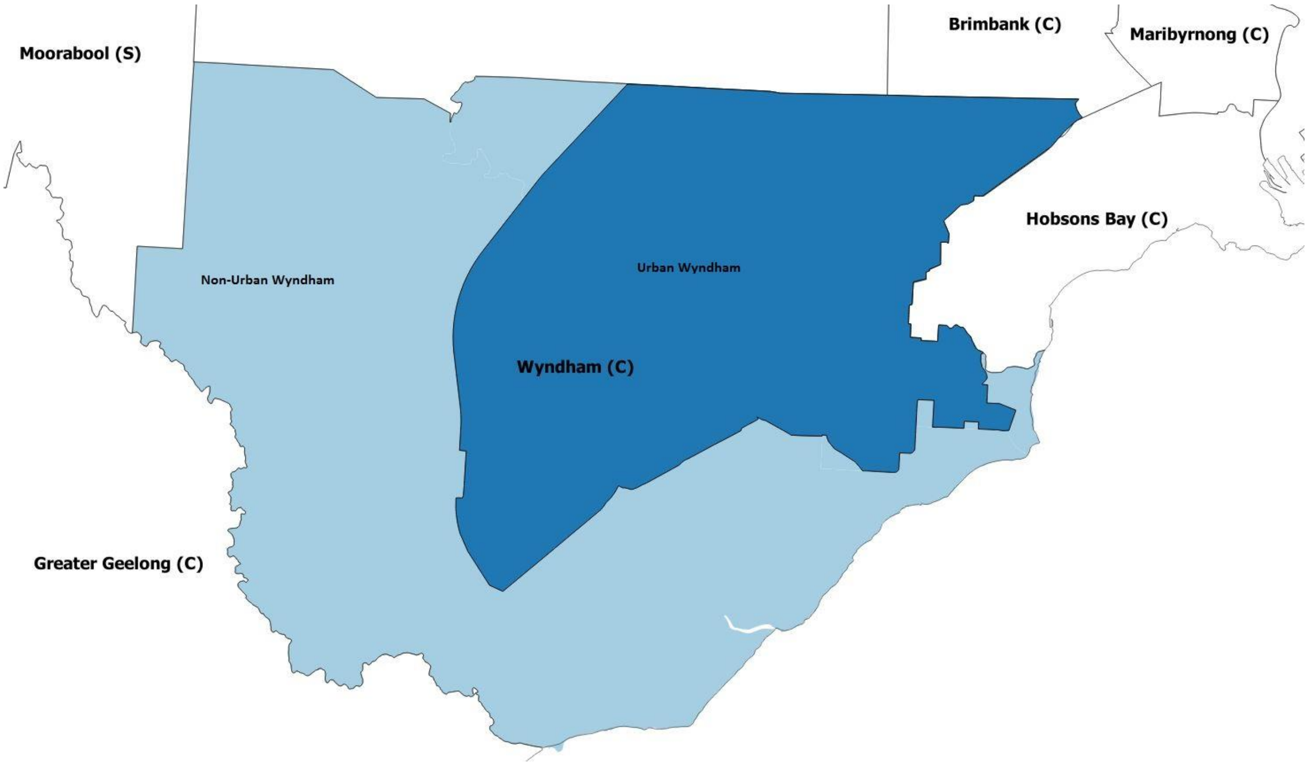
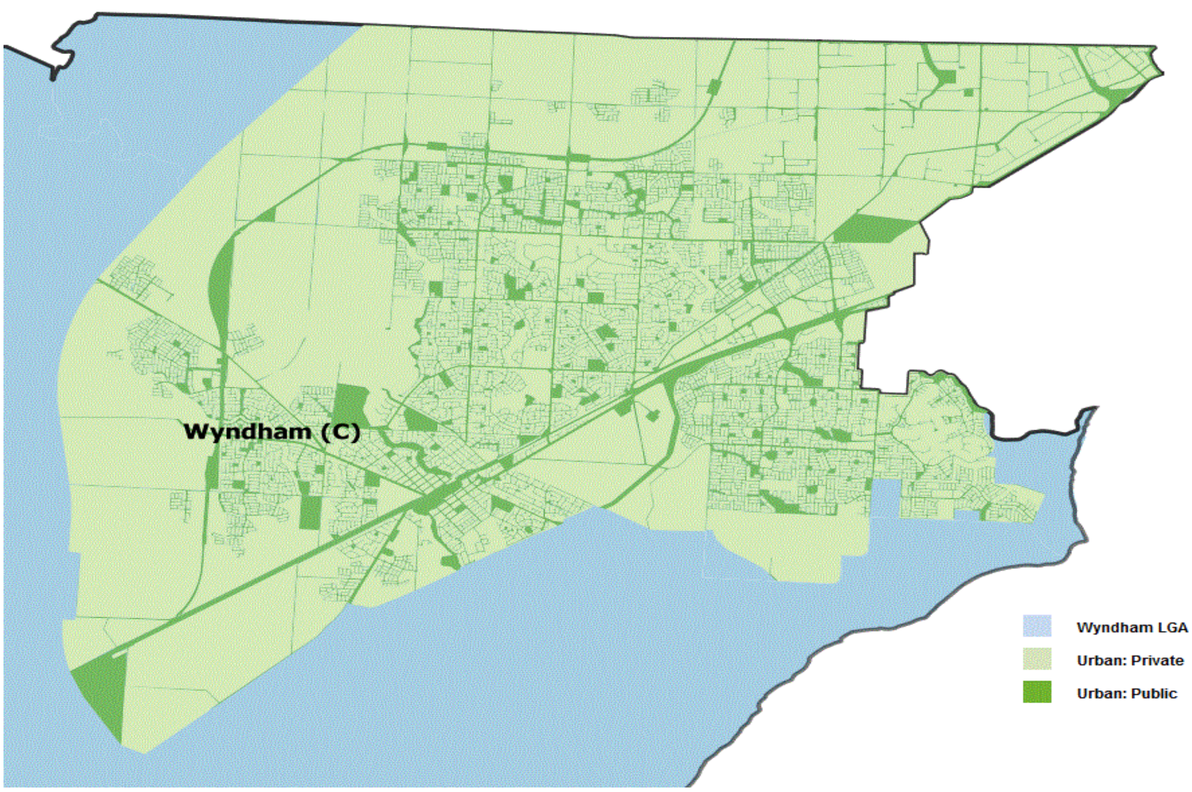



Figure 4.2. *Focused map of Urban Wyndham: Urban Private and Urban Public Areas*



**Land tenure classification**

Land tenure areas were classified based on land use: private land or public space (Table 4.2 below). Areas were aggregated using zoning data and polygons from the *Vicdata* planning database (Vicdata 2016). Tenure types included Urban Public and Urban Private:

- *Urban Public*: Streets, roads, alleyways and nature strips and is mostly an area under the jurisdiction of local government or road management authorities, also includes areas under local, state or federal government, eg parks, libraries, cemeteries and education facilities
- *Urban Private*: Commercial, industrial, residential and other land use types.

Table 4.2. *Land tenure categories from Vicdata planning database used in the study*

| Tenure | Zoning code | Zoning class description |
|---|---|---|
| *Urban Public* | PC, PP, PU, RD | Public Park, Education, Health and Community, Transport, Cemetery Crematorium, Local Government, Conservation Zone, Other public use or service area, Streets, Roads, Nature Strips |
| *Urban Private* | 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 |

**Imagery**

The remote images for 2007 and 2017 were sourced from Wyndham City Council. The 2007 image was taken on October 20, 2007 and had image resolution of 15cm, the 2017 remote image was taken on November 21, 2017 and had an image resolution of 10cm. A significant proportion of the peripheral areas of the Wyndham LGA (primarily grassland and farmland) had no remote image coverage in 2007 and sample points assessed in these areas were additionally checked through Google earth imagery or had data imputed based on the 2017 sample depending on image timing and quality. Due to the stability of land-use in the periphery of the LGA it is not anticipated that this will significantly impact on the sensitivity of the statistical estimates produced for this report.

**Identifying trees from shrubs**

The aim of 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.

Table 4.3. *Classification of variables*

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

*Source: Jacobs 2014*

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**

The dependent sampling regime used for this research (i.e. the same sample was used for each time period) enabled 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 2007 but then classed as Not Tree (2-4) in 2017, 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 Section 8: *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 the cause of tree canopy growth: planting, growth**

If a point was  classed as Tree (1) or Not Tree (2-4) in 2007 but was classed as Tree in 2017, an additional assessment of the sample was done to identify the cause of the growth. The new variable to identify the cause of the canopy cover had three potential values: Canopy Unchanged, Canopy Growth and Canopy Planting

- *Canopy Unchanged:* If the sample point was classed as Tree (1) in 2007 and Tree in (1) 2017;

- *Canopy Growth*: If there was a Tree or Shrub (sapling) near the sample point in 2007 that grew into the sample point in 2017, or a Shrub (2) (sapling) that grew into a Tree (1);
- *Canopy Planting*: Identified as the cause if there was no tree or sapling in the area in 2007 but the sample point was on a Tree (1) in 2017.

**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, misclassification of shrub to tree, misclassification of tree to shrub, 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.*

## 5. OUTCOMES

### Canopy cover in Wyndham by spatial area

Wyndham LGA had 3.6% (±0.4%) canopy cover in 2017. The highest canopy cover percentage in 2017 was estimated in Public Urban areas at 7.9% (±0.6%). All spatial areas experienced significant growth in canopy cover during the study period. Wyndham LGA experienced a 1.2% ($p<0.01$) increase since 2007. Public Urban Area had the highest canopy cover growth of all spatial areas estimated between 2007 and 2017 (+2.2%), followed by the Urban Area at +1.6%. The highest relative growth in canopy cover was experienced in the Wyndham Urban Area where canopy cover increased by +52% over the ten year period.

Table 5.1. *Canopy cover by spatial area in Wyndham, 2007 to 2017*

| Spatial Area | 2007 | | 2017 | | Change | | Relative change |
|---|---|---|---|---|---|---|---|
| | % | *se* | % | *se* | % | *p* | % |
| **Wyndham** | 2.4 | *0.3* | 3.6 | *0.4* | 1.2 | 0.00 | +51 |
| **Urban Area** | 3.1 | *0.4* | 4.7 | *0.5* | 1.6 | 0.00 | +52 |
| **Private Urban Area** | 2.4 | *0.3* | 3.4 | *0.4* | 1.1 | 0.01 | +45 |
| **Public Urban Area** | 5.6 | *0.5* | 7.9 | *0.6* | 2.2 | 0.00 | +40 |

### Net change and churn

Canopy cover is a dynamic indicator, thus canopy cover increased and decreased in all four areas assessed in the study, with the net estimate presented potentially hiding high activity or 'churn' in canopy cover over the ten year period (Table 5.2 below). The areas assessed in Wyndham all had very low amount of churn and very few trees were lost due to construction or removal. Some areas however, experienced slightly more churn than others with the cause of loss having different impacts on the net change. The greatest churn in canopy cover was in the Public Urban Area where the high net change (+2.2%) was due to largest growth in canopy cover (+3.0%) accompanied by the largest loss (-0.8%).

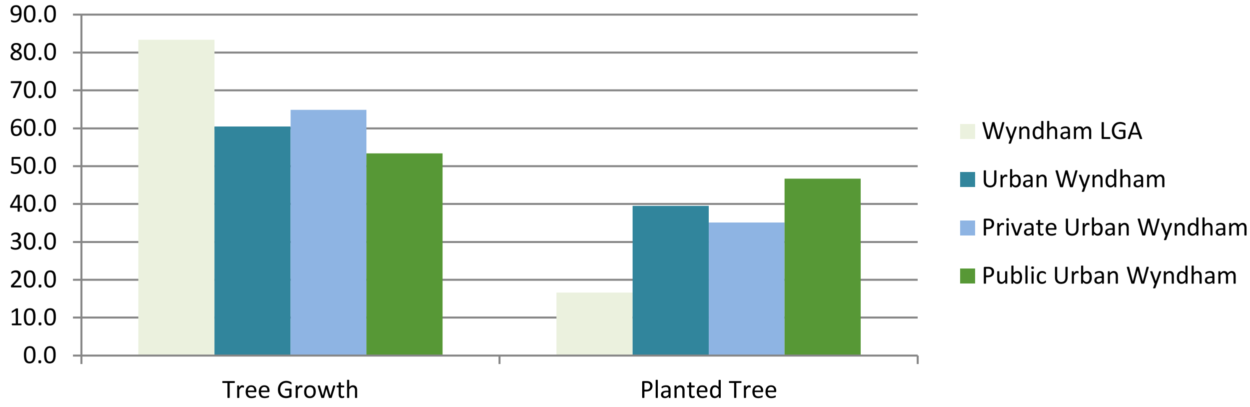
Table 5.2. *Percent loss and gain (churn) in tree canopy cover between 2007 and 2017*

| | Growth and loss | | |
|---|---|---|---|
| Spatial Area | Decrease | Increase | Net change |
| **Wyndham** | -0.2 | 1.4 | 1.2 |
| **Urban Area** | -0.6 | 2.2 | 1.6 |
| **Private Urban Area** | -0.7 | 1.8 | 1.1 |
| **Public Urban Area** | -0.8 | 3.0 | 2.2 |

### Distribution of canopy cover

Figure 5.1 below shows that canopy cover growth between 2007 and 2017 was the result of one of either two variables: Tree/shrub growth or due to direct tree planting. Public Urban Wyndham had the highest proportion of canopy cover resulting from direct tree planting (47%) between 2007 and 2017.

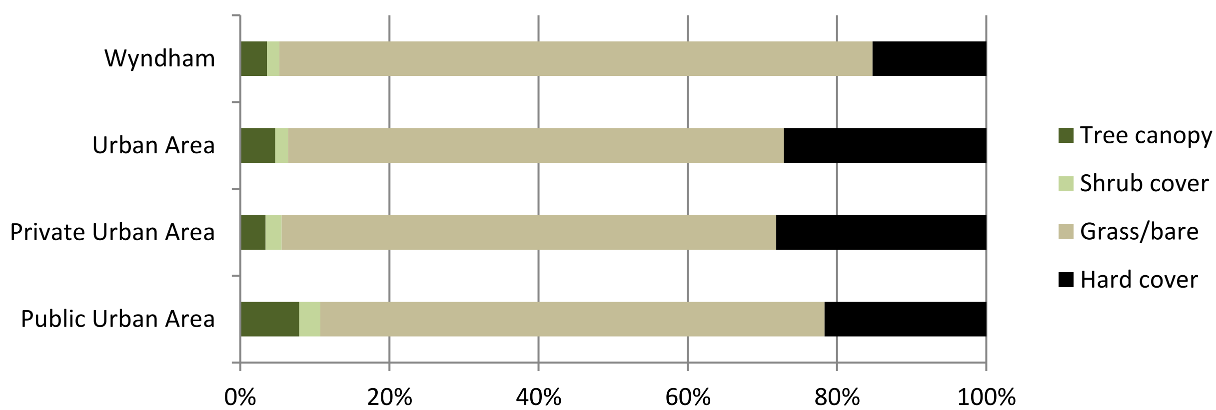
Figure 5.1. *Source of canopy cover growth between 2007 and 2017*




**Cover class and dynamic change**

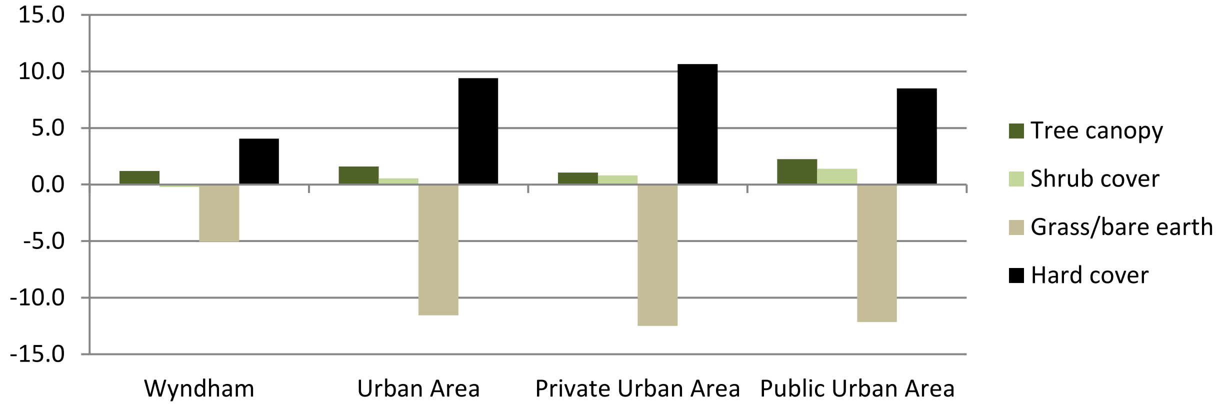
The relative proportions of different types of land cover (trees, shrubs, grass/ bare or hard surface) were different for each spatial area. This is largely a reflection of economic and social uses of the spatial areas as well as prevailing biophysical features. In 2017 all areas were dominated by grass or bare earth (primarily farmland and grassland) ranging from 79% for Wyndham LGA to 66% for the Wyndham Urban Area. Wyndham Private Urban Area, which encompasses industrial, business/commercial and residential areas, recorded the highest hard surface proportion at 28.2% (±1.0%).

Figure 5.2. *Cover class in 2017 by spatial area*




The most consistent and significant ($p<0.01$) estimates across all spatial areas, was the growth of hard surfaces between 2007 and 2017. The growth in hard surfaces and canopy cover was largely at the expense of grass or bare earth. Figure 5.3 below shows that the increase in canopy cover and hard surfaces is a mirror image of the decline in grass and bare earth for all the spatial areas assessed.

Figure 5.3. *Change in cover class between 2007 and 2017 by spatial area*




**Change in land Surface**

Since 2007 to 2017 it is estimated that an additional 2195 ha of hard surface was added to Wyndham LGA and this was largely at the loss of 2738 ha of grass or bare earth. Significant surface area of canopy cover was also added to the LGA of Wyndham, estimated at 651 ha over the ten year period (Table 5.3 below).

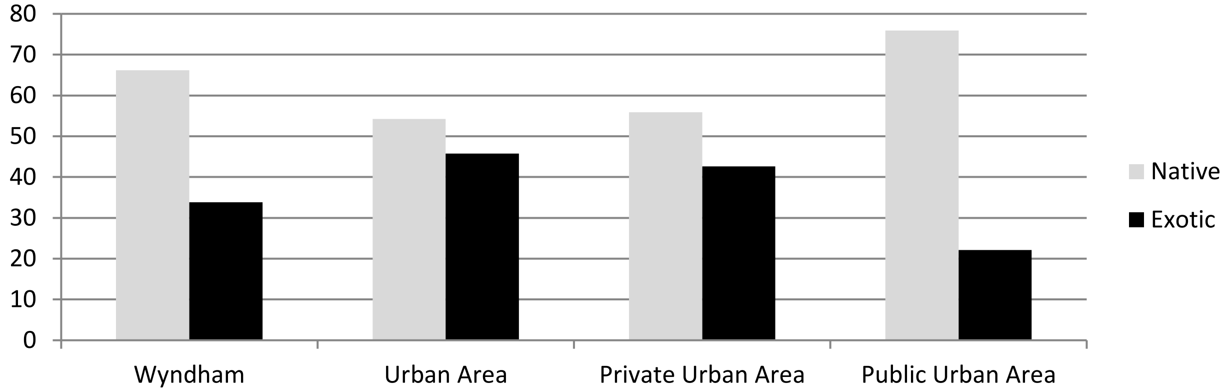
Table 5.3. *Change in canopy cover, hard cover and grass/ bare earth by percent and hectare, 2007-2017*

| Spatial area | 2007 | | | 2017 | | | Change | |
|---|---|---|---|---|---|---|---|---|
| | % | Se | Area ha | % | Se | Area ha | % | Area ha |
| **Canopy cover** | | | | | | | | |
| *Wyndham* | 2.4 | *0.3* | 1274 | 3.6 | *0.4* | 1924 | 1.2 | 651 |
| Urban Area | 3.1 | *0.4* | 706 | 4.7 | *0.5* | 1071 | 1.6 | 365 |
| Private Urban Area | 2.4 | *0.3* | 433 | 3.4 | *0.4* | 626 | 1.1 | 193 |
| Public Urban Area | 5.7 | *0.5* | 271 | 7.9 | *0.6* | 378 | 2.3 | 108 |
| **Hard cover** | | | | | | | | |
| *Wyndham* | 11.2 | *0.7* | 6071 | 15.3 | *0.8* | 8267 | 4.1 | 2195 |
| Urban Area | 17.8 | *0.9* | 4045 | 27.2 | *1.0* | 6187 | 9.4 | 2142 |
| Private Urban Area | 17.5 | *0.8* | 3223 | 28.2 | *1.0* | 5184 | 10.7 | 1961 |
| Public Urban Area | 13.2 | *0.8* | 632 | 21.7 | *0.9* | 1039 | 8.5 | 407 |
| **Grass/bare earth** | | | | | | | | |
| *Wyndham* | 84.6 | *1.6* | 45834 | 79.5 | *1.8* | 43096 | -5.1 | -2738 |
| Urban Area | 78.0 | *1.8* | 17776 | 66.5 | *2.1* | 15144 | -11.6 | -2632 |
| Private Urban Area | 78.8 | *1.8* | 14511 | 66.3 | *2.1* | 12209 | -12.5 | -2302 |
| Public Urban Area | 79.8 | *1.8* | 3819 | 67.6 | *2.1* | 3237 | -12.2 | -582 |

**Tree species by spatial area**

Canopy cover classified as native (*Eucalyptus*/ *Acacia*/ *Melaleuca*) was 66% of the sampled canopy of Wyndham and that proportion varied considerably between spatial areas (Figure 5.4). Wyndham Public Area (76%) had the largest percentage of native canopy cover and Wyndham Urban Area had the lowest proportion of native canopy cover. All areas in Wyndham had a majority of canopy cover (50% or more) classified as native.

Figure 5.4. *Map of native (Eucalyptus/ Acacia/ Melaleuca) canopy cover in Wyndham by spatial area, in 2017*

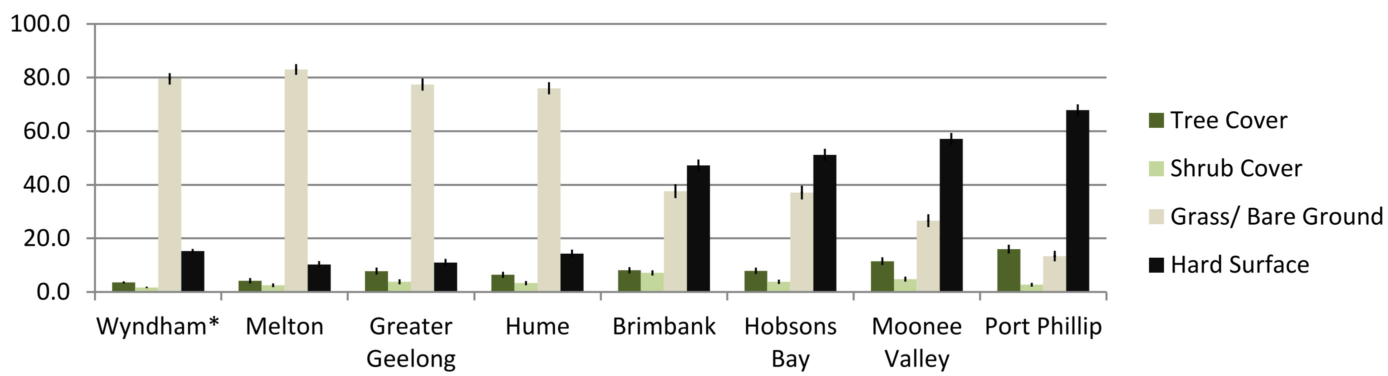


## 6. EVALUATION AND DISCUSSION

**Comparison of the City of Wyndham to adjoining LGAs**

When comparing the results from this study to the 2017 study '*Where should all the trees go? Investigating the impact of tree canopy cover on socioeconomic status and wellbeing in LGA's* conducted by Amati et al. (2017), Wyndham LGA has a canopy cover similar to other areas on the western periphery of Melbourne such as Melton, Greater Geelong and Hume (Figure 6.1). These western suburbs are dominated by grassland and farmland with comparatively low canopy cover (from 7.8% to 3.6%). More developed and populous LGAs further to the east and closer to the urban centre had much larger proportions of hard surfaces (68% to 47%) and higher canopy cover (16% to 8%). Overall, Wyndham's 2017 canopy cover of 3.6% (±0.4%) is a comparatively low canopy cover percentage compared to Victorian LGAs which in 2017 had a median canopy cover percentage of 16.3% (Amati et al. 2017).

Figure 6.1. *Comparison of this study* with Amati et al. 2017*




**Tenure and change**

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 compared to private land (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 Wyndham, the estimated canopy cover on private urban land increased significantly ($p$<0.01) in all spatial areas assessed. Public space was the most important and disproportionate contributor to the net canopy cover gains in Wyndham which is consistent with the literature on public land as a major contributor to net canopy cover and canopy cover growth in urban areas (Kaspar et al. 2017; Dobbs et al. 2013).

**Cover classes**

Quantifying cover classes for Wyndham offers 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 4.1% over the period assessed, however, new housing development is not the only factor in hard cover increase: the expansion of driveways, railways, 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 2007 to 2017 relates directly to a significant increase of not only hard surfaces but also of tree canopy cover for every spatial area.

**Population change, housing development and change in canopy cover**

The universal increase in canopy cover across the spatial areas assessed in this study is connected to the increase in population and housing which indicates that development is increasing canopy cover growth. This phenomenon is because Wyndham LGA already had such a low tree canopy cover and housing development, roads and wetland construction associated with increasing population also involved extensive tree plantings. Table 6.1 below shows that in the ten year period between 2006 and 2016 the City of Wyndham's population increased by 51.9%; over a similar ten year period to the census (2007-2017), the canopy cover increased by 51.1%: an almost exact relative increase as the population growth.

Table 6.1 *Population change and canopy cover change in Wyndham, 2006-2016 and 2007-2017*

| Year | Population | % Population increase |
|---|---|---|
| **2006** | 112,695 | .. |
| **2016** | 217,122 | 51.9 |
| **Year** | **Canopy cover %** | **% Canopy increase** |
| **2007** | 2.4 | .. |
| **2017** | 3.6 | 51.1 |

In one current forecast, Wyndham's population is expected to increase by 74.2% from 2016 to reach 435,832 by 2036 (ABS 2019). If the trend of development and tree planting by public and private enterprise is continued, it is reasonable to expect an increase in canopy cover of a similar magnitude.

Figure 6.2 below shows the dramatic landscape changes associated with urban development in Wyndham Urban Area (Point Cook) to demonstrate the direct link to development, street tree plantings and canopy cover increase. In 2007 almost the entire area of the image was grassland, whereas ten years later, the area was developed and included significant street tree plantings.

Figure 6.2 *Greenfield housing development in the Wyndham Urban Private Area, 2007 and 2017*

Figure 6.3 below shows the drastic changes to the landscape in the area between Honolulu Dr and Barnstormer Blvd in the suburb of Point Cook. Since 2007 the landscape has changed from universal grass or bare earth to a more complex urban landscape that now also includes tree canopy cover, shrub cover and hard surfaces. The primary source of canopy cover in the image is from public street tree and waterway plantings.

Figure 6.3 *Greenfield wetland park creation in the Wyndham Urban Public Area, 2007 and 2017*

**Comparative canopy cover targets**

The City of Melbourne Urban Forest Strategy (2012), sets a target of 40% canopy cover by 2040, increasing from 22% in 2016. Melbourne's Urban Forest Strategy notes that one of the most cost efficient and effective mitigation strategies for the urban heat island effect is to ensure a minimum canopy cover of 30%. LGAs to the west of Melbourne however, have a variety of characteristics that make urban greening objectives difficult to achieve such as poor soil characteristics and low rainfall. Conversely, rapid ongoing development in the area is also an opportunity for Wyndham to achieve ambitious targets, as this research has shown that in the period between 2007 and 2017, population growth and housing development is correlated to increased canopy cover. Many other Councils in the area also have targets to increase canopy cover and these targets will require extensive tree protection, tree planting policies as well as collaborative efforts to bring the private sector and the community in tree planting initiatives.

Table 6.2 *Urban forest strategies and canopy cover targets for selected councils near Wyndham*

| Area | Urban Forest Strategy | Canopy cover | Target canopy cover |
|---|---|---|---|
| Melbourne | Yes (2012) | 22% (2016) | 40% canopy cover by 2040 |
| Wyndham | Yes (2017) | 7.9% (2017)* | 25% canopy cover for streetscapes by 2040 |
| Greater Geelong | Yes (2015) | 7.8% (2017)** | 25% canopy cover by 2045 |
| Brimbank | Yes (2016) | 8.1% (2017)** | 30% canopy cover by 2046 |

* This study (Public Urban Area)

** Amati et al. 2017

## 7. CONCLUSIONS

Wyndham has a low canopy cover (3.6%, ±0.4%) compared to other LGAs in the Melbourne region, however in the period between 2007 and 2017 the canopy cover grew by a significant amount (+1.2%, $p<0.01$). This increase amounts to a relative increase of +51% over the ten year period. The high relative increase in tree canopy cover percentage was accompanied by significant increases to hard surfaces in all the spatial areas assessed in the LGA and a significant decrease in grass or bare earth. The increase in canopy cover was also uniquely accompanied by very low canopy cover 'churn' which indicates that the existing stock of canopy trees are not being cleared in significant numbers. This also corresponds to the source of growth in canopy cover, with many new trees planted over the ten year period. In Public Urban Wyndham Area for example, up to 47% of the canopy cover growth came from new greenfield tree plantings. Land-use tenure was correspondingly an important factor in canopy cover distribution and change in Wyndham with Public Urban Wyndham having the highest canopy cover (7.9%, ±0.6%) and the highest growth in canopy cover (+2.2%) of all the spatial areas assessed.

One of the most consistent and significant findings in this research was the increase in hard surfaces with canopy cover and the decrease in grass or bare earth. This suggests that the intensity of land use in Wyndham is moving towards the provision of constructed environments and tree centered ecosystem services primarily at the expense of open land. The significant landscape changes estimated in this report have been accompanied by significant population growth and development. Indeed, relative canopy cover growth tracks closely to population growth (Table 6.1). Since the 2016 census, Wyndham's population is projected to grow by 74.2% to reach 435,832 by 2036. In order for Wyndham to keep the canopy cover growth at similar rates, a similar level of tree planting protection, planting and planning will need to be implemented.

Overall, the patterns from this report suggest that in many respects the City of Wyndham's current tree canopy cover protection and planting policies are working because there was extensive evidence of tree planting, and few examples of tree loss from existing trees in the ten year period. For Wyndham to match the ambitious canopy cover targets implemented by other councils in the Melbourne Area however, significant and intensive tree planting and planning initiatives will be required into the future.

## 8. DATA QUALITY, INTREPRETATION AND COMPARISON

**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 proposes 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 Wyndham LGA.

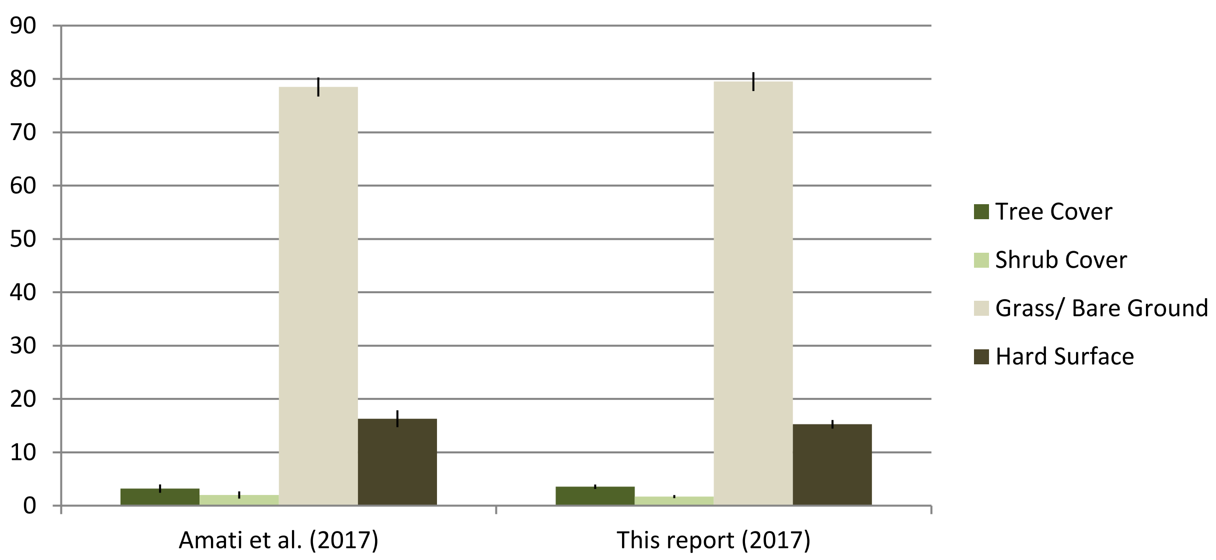
**Canopy species composition**

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 significant number of 'edge' cases (~20%) 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: Wyndham LGA 3.2%, (±0.8) compared to 3.6% (±0.4). 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 thus it is anticipated that the results from this study will give a improved assessment of the canopy cover for the area.

Figure 8.2. *Comparisons of canopy cover from this report with Amati et al. (2017)*



## 9. SUPPLEMENTARY DETAILED TABLES

**Table 9.1 Wyndham Landscape Statistics, 2007**

| | Tree Cover | | Shrub Cover | | Grass/ Bare Ground | | Hard Surface | |
|---|---|---|---|---|---|---|---|---|
| | % | *se* | % | *se* | % | *se* | % | *se* |
| **Wyndham** | 2.4 | *0.3* | 1.9 | *0.3* | 84.6 | *1.6* | 11.2 | *0.7* |
| **Urban Area** | 3.1 | *0.4* | 1.2 | *0.2* | 78.0 | *1.8* | 17.8 | *0.9* |
| **Private Urban Area** | 2.4 | *0.3* | 1.4 | *0.3* | 78.8 | *1.8* | 17.5 | *0.8* |
| **Public Urban Area** | 5.6 | *0.5* | 1.4 | *0.3* | 79.7 | *1.8* | 13.2 | *0.8* |

**Table 9.2 Wyndham Landscape Statistics, 2017**

| | Tree Cover | | Shrub Cover | | Grass/ Bare Ground | | Hard Surface | |
|---|---|---|---|---|---|---|---|---|
| | % | *se* | % | *se* | % | *se* | % | *se* |
| **Wyndham** | 3.6 | *0.4* | 1.7 | *0.3* | 79.5 | *1.8* | 15.3 | *0.8* |
| **Urban Area** | 4.7 | *0.5* | 1.7 | *0.3* | 66.5 | *2.1* | 27.2 | *1.0* |
| **Private Urban Area** | 3.4 | *0.4* | 2.2 | *0.3* | 66.3 | *2.1* | 28.2 | *1.0* |
| **Public Urban Area** | 7.9 | *0.6* | 2.8 | *0.4* | 67.6 | *2.1* | 21.7 | *0.9* |

**Table 9.3. Wyndham Landscape Statistics, change between 2007 and 2017**

| | Tree Cover | | Shrub Cover | | Grass/ Bare Ground | | Hard Surface | |
|---|---|---|---|---|---|---|---|---|
| | % | *p* | % | *p* | % | *p* | % | *p* |
| **Wyndham** | 1.2 | *0.00* | -0.2 | *0.57* | -5.1 | *0.00* | 4.1 | *0.00* |
| **Urban Area** | 1.6 | *0.00* | 0.6 | *0.12* | -11.6 | *0.00* | 9.4 | *0.00* |
| **Private Urban Area** | 1.1 | *0.01* | 0.8 | *0.04* | -12.5 | *0.00* | 10.7 | *0.00* |
| **Public Urban Area** | 2.2 | *0.00* | 1.4 | *0.00* | -12.1 | *0.00* | 8.5 | *0.00* |

## 10. REFERENCES

ABS (2019) *2016 Census QuickStats: Wyndham (C).* www.censusdata.gov.au

Amati, M., Boruff, B., Caccetta, P., Devereux, D., Kaspar, J., Phelan, K., & Saunders, A. (2017) *Where should all the trees go? Investigating the impact of tree canopy cover on socioeconomic status and wellbeing in LGA's.* RMIT University, With: CSIRO Data 61, University of Western Australia, Project number: NY16005.

Brown, H., Katscherian, D., Carter, M., & Spickett, J. (2013) *Cool communities: Urban trees, climate and health*. Workshop held at the Department of Planning on 14 March 2013.

Brunner, J. & Cozens, P. (2013) 'Where Have All the Trees Gone?' Urban Consolidation and the Demise of Urban Vegetation: A Case Study from Western Australia. *Planning, Practice & Research*, 2013 Vol. 28, No. 2, 231–255.

Davies, R. G., Barbosa O., Fuller, R. A., Tratalos, J., Warren, P. H. & Gaston K. J. (2008) City-wide relationships between green spaces, urban land use and topography. *Urban Ecosystems* (2008) 11:269–287.

Dobbs, C., Kendal, D., & Nitschke, C. (2013) The effects of land tenure and land use on the urban forest structure and composition of Melbourne. *Urban Forestry & Urban Greening 12 (2013) 417–425*.

Fuller, R. A., Irvine, K. N., Devine-Wright, P., Warren, P. H. & Gaston, K. J. (2007) Psychological benefits of greenspace increase with biodiversity. *Biol. Letters (2007)* 3, 390–394.

Gómez-Baggethun, E., & Barton, D. N. (2013). Classifying and valuing ecosystem services for urban planning. *Ecological Economics*, 86, 235–245.

Hall, T. (2010) The death of the Australian backyard - a lesson from Canberra. *Urban Research Program, Griffith University*.

Hardin, P. J., Jensen, R. R., (2007). The effect of urban leaf area on summertime urban surface kinetic temperatures: a Terre Haute case study. Urban Forestry & Urban Greening. 6, 63–72.

Hill, E., Dorfman, J. H. & Kramer, E. (2007) Evaluating the impact of government land use policies on tree canopy coverage. *Land Use Policy 27* (2010) 407–414.

Jacobs, B., Mikhailovich, N., and Moy, C. (2014) Benchmarking Australia's Urban Tree Canopy: An i-Tree Assessment, prepared for Horticulture Australia Limited by the Institute for Sustainable Futures, University of Technology Sydney.

Kaspar, J Kendal, D Sore, R and Livesley, S. J. (2017) Random point sampling to detect gain and loss in tree canopy cover in response to urban densification, *Urban Forest Urban Greening,* 24, 26-34.

McPherson, E. G., Simpson, J. R., Xiao, Q., & Wu, C. (2011) Million trees Los Angeles canopy cover and benefit assessment. *Landscape and Urban Planning 99* (2011) 40–50.

Mincey, S. K., Schmitt-Harsh, M. & Thurau, R. (2013) Zoning, land use, and urban tree canopy cover: The importance of scale. *Urban Forestry & Urban Greening 12* (2013) 191– 199.

Nowak, D. J., (2002). *The effects of Urban trees on Urban Air Quality*. USDA Forest Service, Syracuse, NY.

Nowak, D. J. & Greenfield, E. J. (2012) Tree and impervious cover change in U.S. cities. *Urban Forestry & Urban Greening 11* (2012) 21– 30.

Parmehr, E., Amati, M., Taylor, E. J., & Livesley, S. J. (2016) Estimation of urban tree canopy cover using random point sampling and remote sensing methods. *Urban Forestry & Urban Greening 20* (2016). 160–170.

Richardson, J. J. & Moskal, L. M. (2014) Uncertainty in urban forest canopy assessment: Lessons from Seattle, WA, USA. *Urban Forestry & Urban Greening 13* (2014). 152–157.

Rogers, K. & Jaluzot, A. (2015) *Oxford i-Tree Canopy Cover Assessment*. Treeconomics, Oxford, UK.

Roy, S., Byrne, J. & Pickering, C. (2012) A systematic quantitative review of urban tree benefits, costs, and assessment methods across cities in different climatic zones. *Urban Forestry & Urban Greening 11* (2012) 351– 363.

Sander, H., Polasky, S., Haight, R. G., (2010). The value of urban tree cover: A hedonic property price model in Ramsey and Dakota Counties, Minnesota, USA. *Ecological Economics*. 69, 1646–1656.

Smardon, R. C., (1988). Perception and Aesthetics of the Urban Environment: Review of the Role of Vegetation. *Landscape and Urban Planning*, 15, 85-106.

Taylor, M. S., Wheeler, B. W., White, M. P., Economou, T., & Osborne, N. J. (2015) Research note: Urban street tree density and antidepressant prescription rates—A cross-sectional study in London, UK. *Landscape and Urban Planning* 136 (2015). 174–179.

Tyrvainen, L., & Miettinen, A., (2000). Property Prices and Urban Forest Amenities. *Journal of Environmental Economics and Managemen*t. 39, 205-223.

Vicdata (2016) *Vicmap Planning*. Department of Sustainability and Environment, Victoria. https://www.data.vic.gov.au/.

Weber, F., Kowarik, I., & Säumel, I., (2014). Herbaceous plants as filters: Immobilization of particulates along urban street corridors. *Environmental Pollution*. 186, 234-240.

**<END OF REPORT>**