

Aerial Measurement of Vegetation Cover 2022

Ku-ring-gai Council

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Executive Summary

Ku-ring-gai Council engaged ArborCarbon to acquire, process and deliver remotely sensed data that will be used to determine their current canopy cover, to measure the progress towards the Council's canopy cover targets, and to provide insight into where the Council should be targeting their efforts to increase canopy.

The aircraft-mounted ArborCam was used to acquire high resolution imagery to measure surface temperatures and accurately quantify canopy cover and condition. High-resolution airborne multispectral imagery was acquired at 16,000 ft above ground level over the Council with cloudless conditions on the 22nd of March 2022. Vegetation strata and canopy cover statistics were extracted and categorized into different height strata and various land classification boundaries.

The main findings of this report are:

- The total vegetation cover in Ku-ring-gai Council was 68.9% (5880.4 ha) of the total LGA area of 8539.5 ha.
- Canopy (vegetation 3m and above) covered 50% (4265.3 ha) of the Council.
- The total vegetation cover of the urban area of Ku-ring-gai Council was 63.8% (4328.5 ha).
- Canopy covered 43.6% (2959.6 ha) of the urban area.
- Ku-ring-gai Council-owned land had the highest proportional canopy at 57.1%, and land classified as 'Other' had 56.1% canopy cover. Private land had 34.9% proportional canopy cover.
- In terms of contribution to overall canopy cover (excluding C1), private land contributed 48.6%, Council owned land contributed 43.3%, and land classified as 'other' contributed 8.2%.
- North Turramurra had the greatest canopy cover as a proportion of suburb area (63.3%), while Roseville had the least (33.1%). In terms of overall Council canopy, North Turramurra contributed the most (17.3%) while Warrawee contributed the least (1.3%).
- Regarding urban area only, South Turramurra had the greatest canopy cover as a proportion of suburb area (57.2%), while Roseville had the least (33.1%). In terms of contribution to overall canopy cover in the urban area, St Ives contributed the most (15.4%) while Warrawee contributed the least (1.8%).
- In terms of Town Centres, Turramurra Town Centre had the greatest canopy cover as a proportion of its area (41.9%), while Roseville Town Centre had the least (31.6%). In terms of contribution to the overall canopy cover of Town Centres, Turramurra Town Centre contributed the most (22.3%) while Roseville Town Centre contributed the least (6.2%).
- Land classified as E2 (Environmental Conservation) had the highest proportional canopy cover, at 83% of its total area, while land classified as B4 (Mixed Use) had the lowest proportional canopy cover (12.3%). In terms of contribution to the overall canopy cover of the LGA, E1 (National Parks) contributed the most towards canopy (30.6%), followed by R2 (Low Density Residential) and E2 (Environmental Conservation) at 27.4 and 24.3%, respectively.
- Overall, canopy cover of road reserves was 35.5%.

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1 Introduction

In 2020, Ku-ring-gai Council identified their LGA wide canopy (vegetation >3m in height) cover to be at 51.4%, and the canopy cover of their 'urban' area (excluding land zoned C1 – National Parks) to be 45%. This is considered a good level on a global scale. However, the Council has an aging tree population and holds its remaining canopy in high value.

The Ku-ring-gai community places a high value on the natural environment, its biodiversity, the sense of place, their streets' green and leafy nature, and its diverse heritage. Improving the quality and diversity of the urban forest, and protecting, increasing, and managing the urban tree canopy, is important to Council.

The Council recently developed an Urban Forest Strategy, with four urban forest principles: 'retain and protect'; 'expand and integrate'; 'monitor and maintain'; and 'collaborate and incentivise'. As part of 'monitor and maintain', the Council set a goal to monitor vegetation and canopy cover. This includes acquiring airborne imagery across the Council every two years, to identify changes in vegetation cover.

ArborCarbon has recently developed a unique 11-band airborne multispectral and thermal camera system (ArborCam) optimized for accurately detecting vegetation and subtle changes in vegetation condition. Ku-ring-gai Council engaged ArborCarbon to acquire high resolution imagery to measure vegetation cover and condition across the Council using this camera system. This system captured imagery in 2020 and will use the same metrics and parameters. The results of this acquisition can be directly compared to those from the 2020 acquisition and will be used by the Council to track progress towards the vision in the Urban Forest Strategy.

2 Methods

2.1 Acquisition of high-resolution airborne imagery

High-resolution airborne multispectral imagery was acquired at 16,000 ft above ground level over the Council in cloudless conditions between 09:45 and 16:15 on March 22nd 2022. The imagery was acquired for this project with the ArborCam system with a ground sample distance (GSD) ranging from 14 cm/pixel to 42 cm/pixel, dependent on the spectral band. Imagery was comprised of three broad bands in the visible (VIS) region of the electromagnetic spectrum, and an additional seven narrow bands strategically positioned in the VIS and near infra-red (NIR) regions to detect subtle variations and changes in vegetation condition. Thermal imagery was acquired concurrently with a GSD of 175 cm/pixel. The maximum daily temperature was 29.5°C at Sydney (Observatory Hill) (BoM reference: 66062).

2.2 Data processing and analysis

The high-resolution airborne imagery datasets were geometrically corrected and orthorectified using Precise Point Positioning (PPP) Global Navigation Satellite System (GNSS). A Digital Surface Model (DSM) was generated from the acquired imagery for the full extent of the Council and aligned to the publicly available Geoscience Australia LiDAR-derived 1m Digital Terrain Model (DTM), and the data acquired in 2020. Vegetation heights were calculated as the difference between the DSM and DTM. This enabled the stratification of vegetation into five pre-determined height categories: <3m, 3-5m, 5-10m, 10-15m, 15-20m, and >20m. Canopy is considered any vegetation >3m in height.

Bands across the VIS-NIR were used to detect all living vegetation in sun and shadow. Vegetation that was not photosynthesizing at the time of acquisition, such as dead wood in tree crowns and dead grass, was not classified as vegetation. Height-stratified vegetation cover statistics were calculated for the entire LGA, urban area (Figure 1), land ownership category (Figure 2), each suburb boundary (Figure 3), each suburb clipped to the urban boundary, Town Centres (Figure 4), Land Use Zones (Figure 5), and road reserves (Figure 6) in Ku-ring-gai Council.

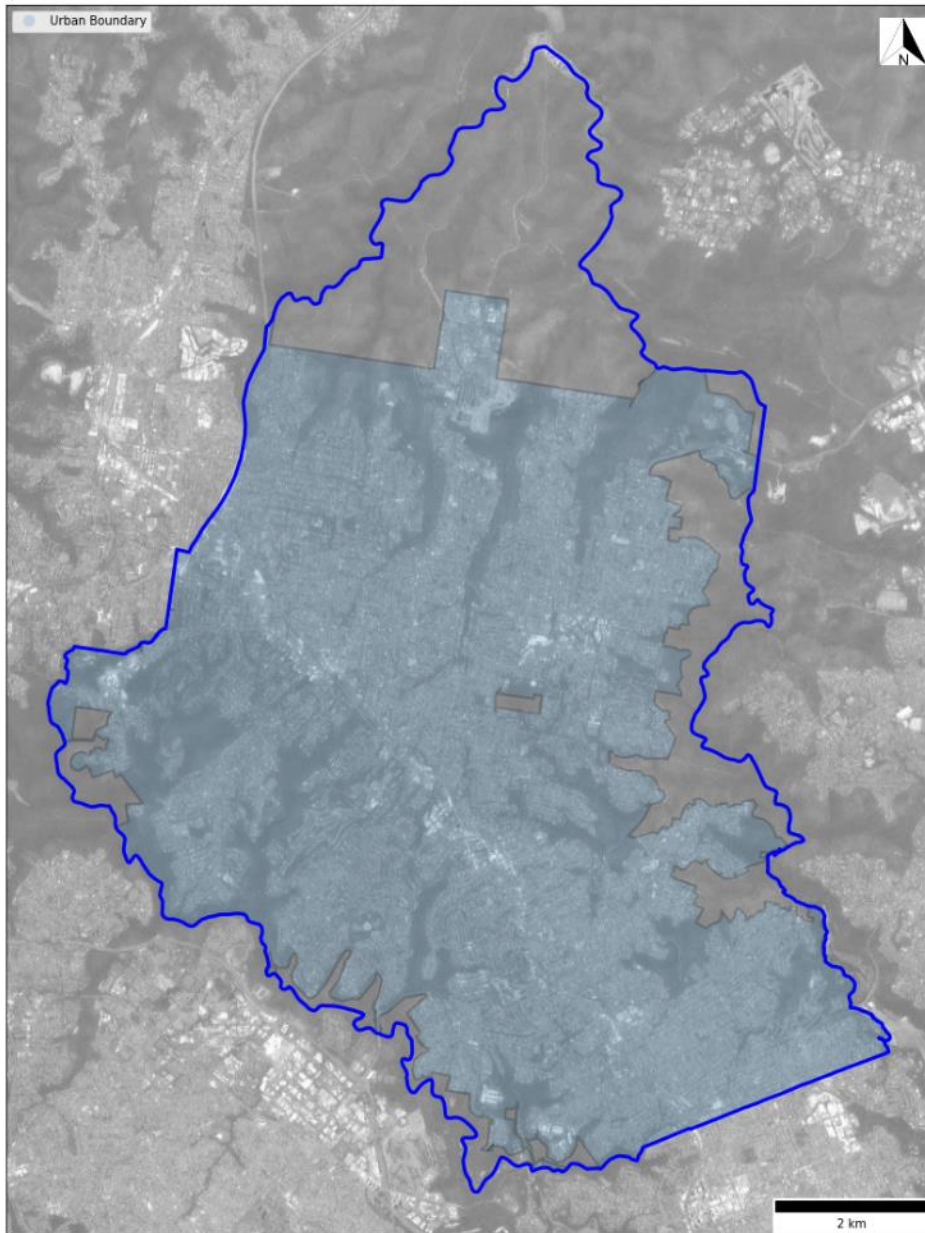


Figure 1: Urban boundary (blue shaded) within the total Ku-ring-gai LGA boundary.

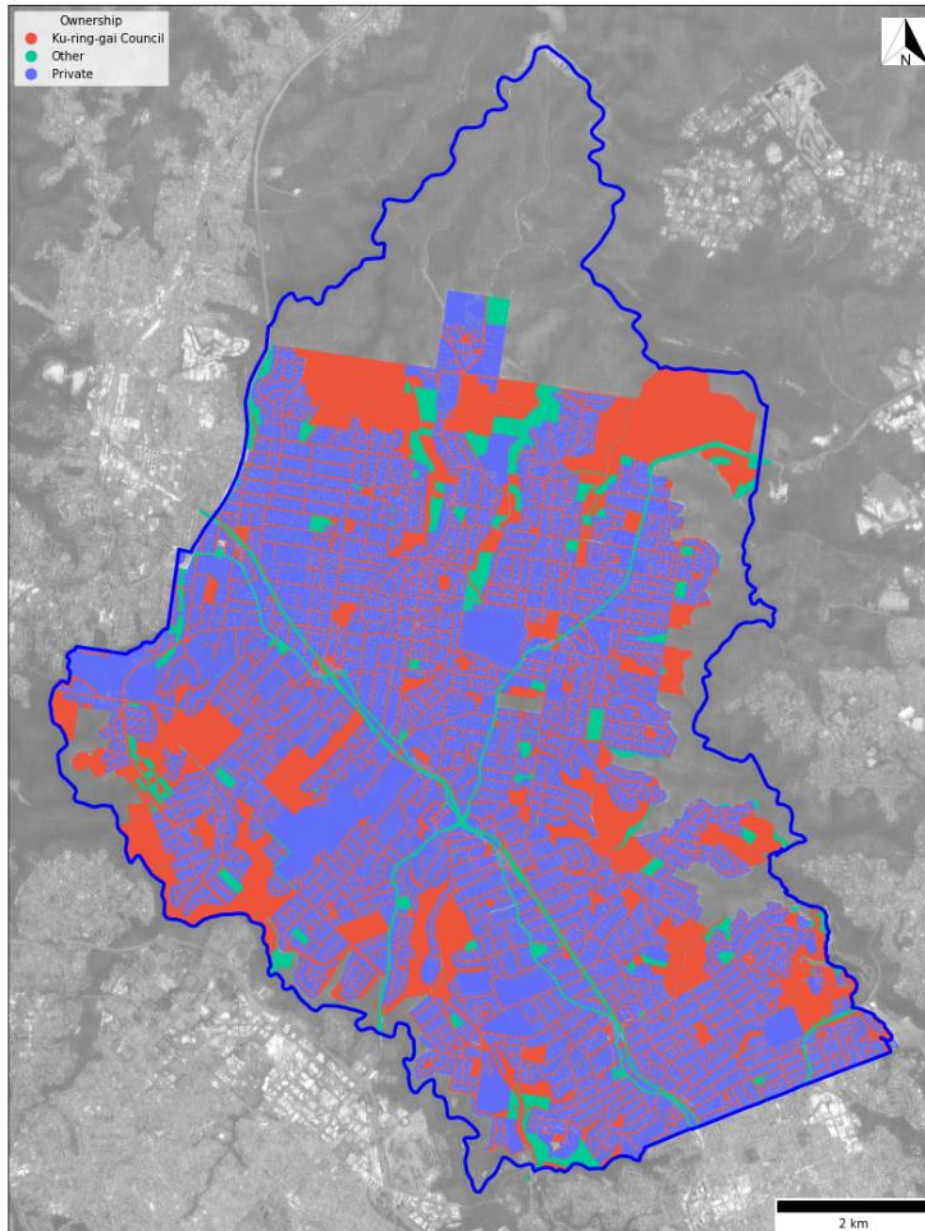


Figure 2: Land ownership classification of the urban boundary, showing private land (blue), Ku-ring-gai Council-owned land (red), and land classified as 'other' (green) within the total Ku-ring-gai LGA boundary.

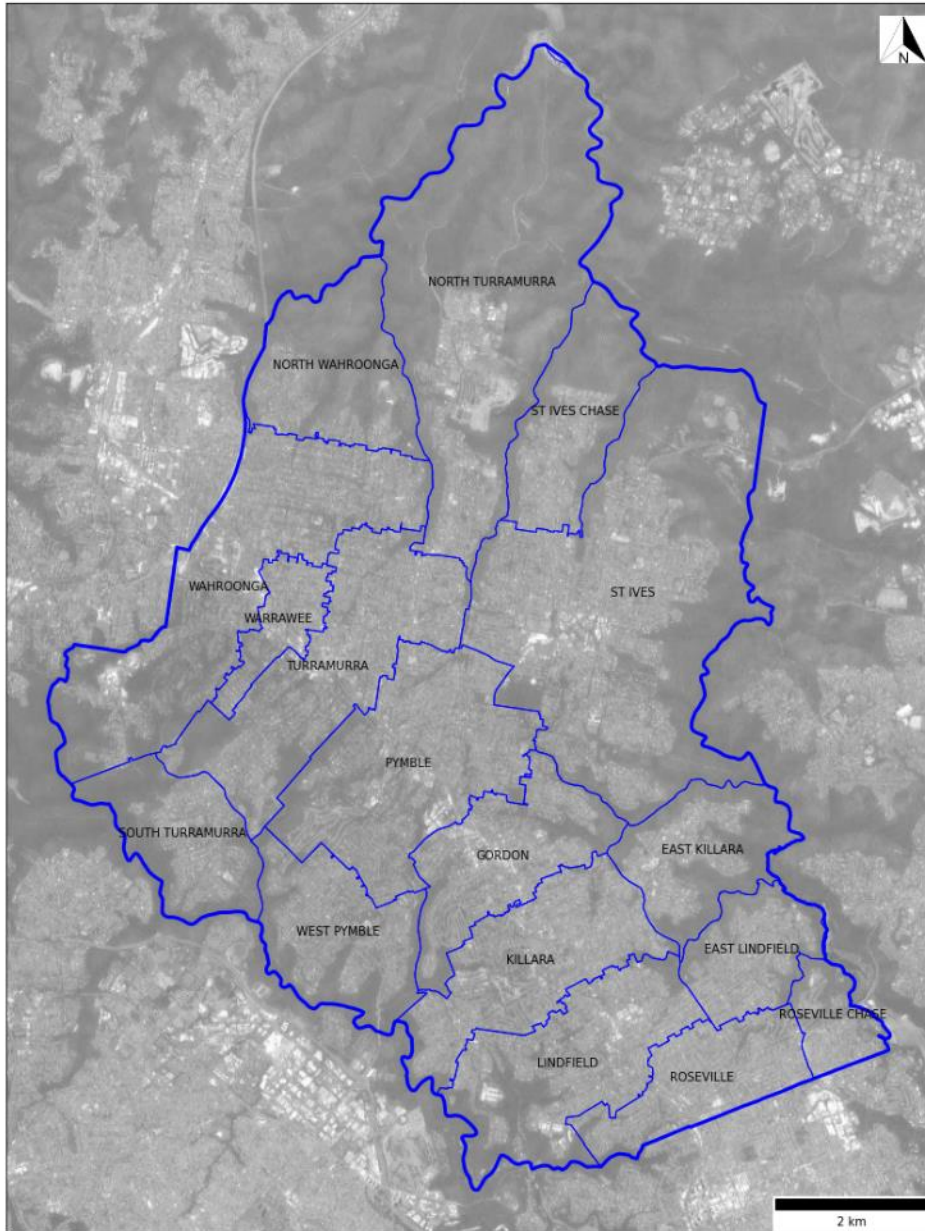


Figure 3: Suburb boundaries within Ku-ring-gai LGA.

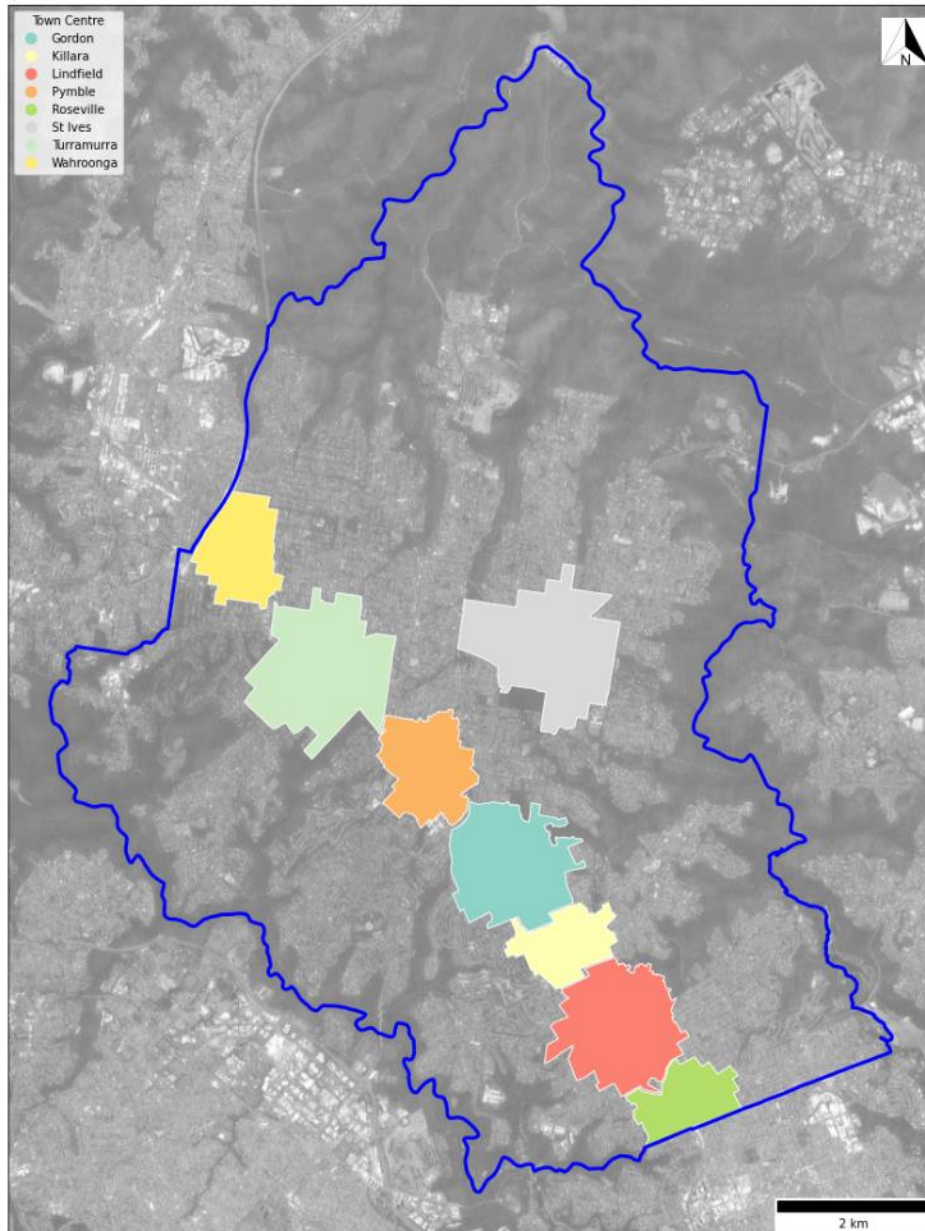


Figure 4: Town Centre boundaries within the total Ku-ring-gai LGA boundary.

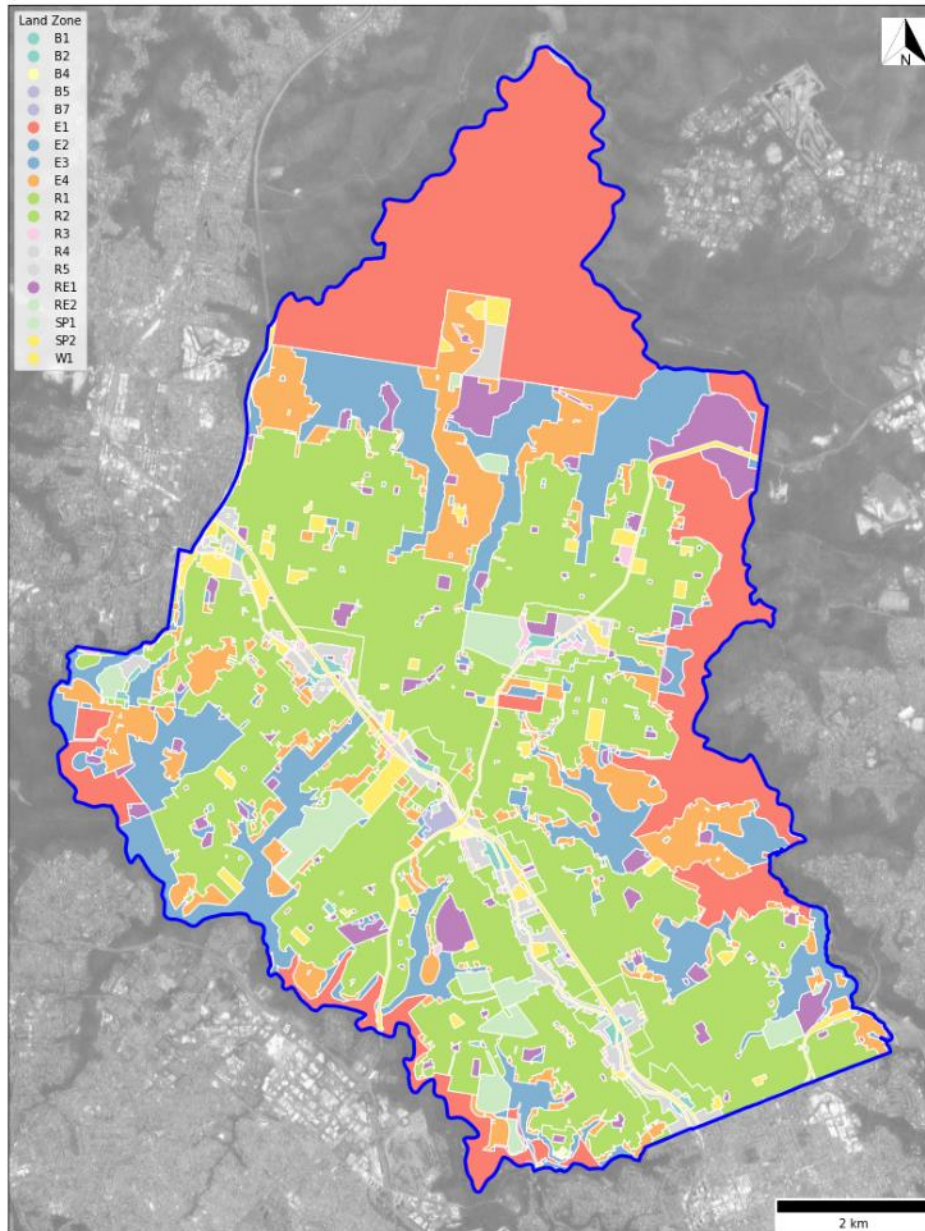


Figure 5: Land Use Zones within the total Ku-ring-gai LGA boundary.

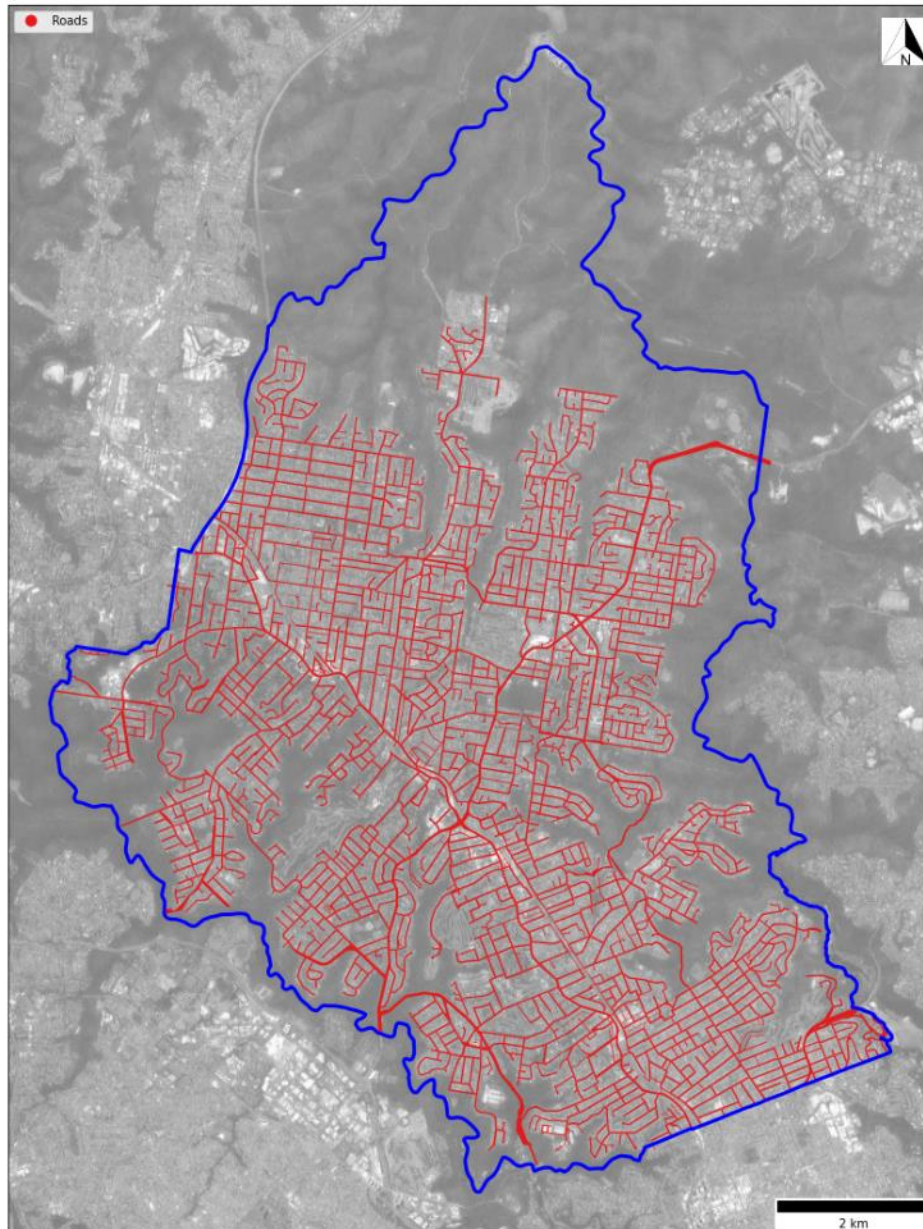


Figure 6: Road reserves within the total Ku-ring-gai LGA boundary.

3 Results and Discussion

The acquired data was processed to produce high resolution 3-band Red, Green and Blue (RGB) imagery (Figure 7), 7-band multispectral imagery (represented by a False Colour Composite in Figure 8), height-stratified vegetation cover (Figure 9), land surface temperature (Figure 10), and vegetation condition (Figure 11), across the 8539.5 ha of Ku-ring-gai Council.

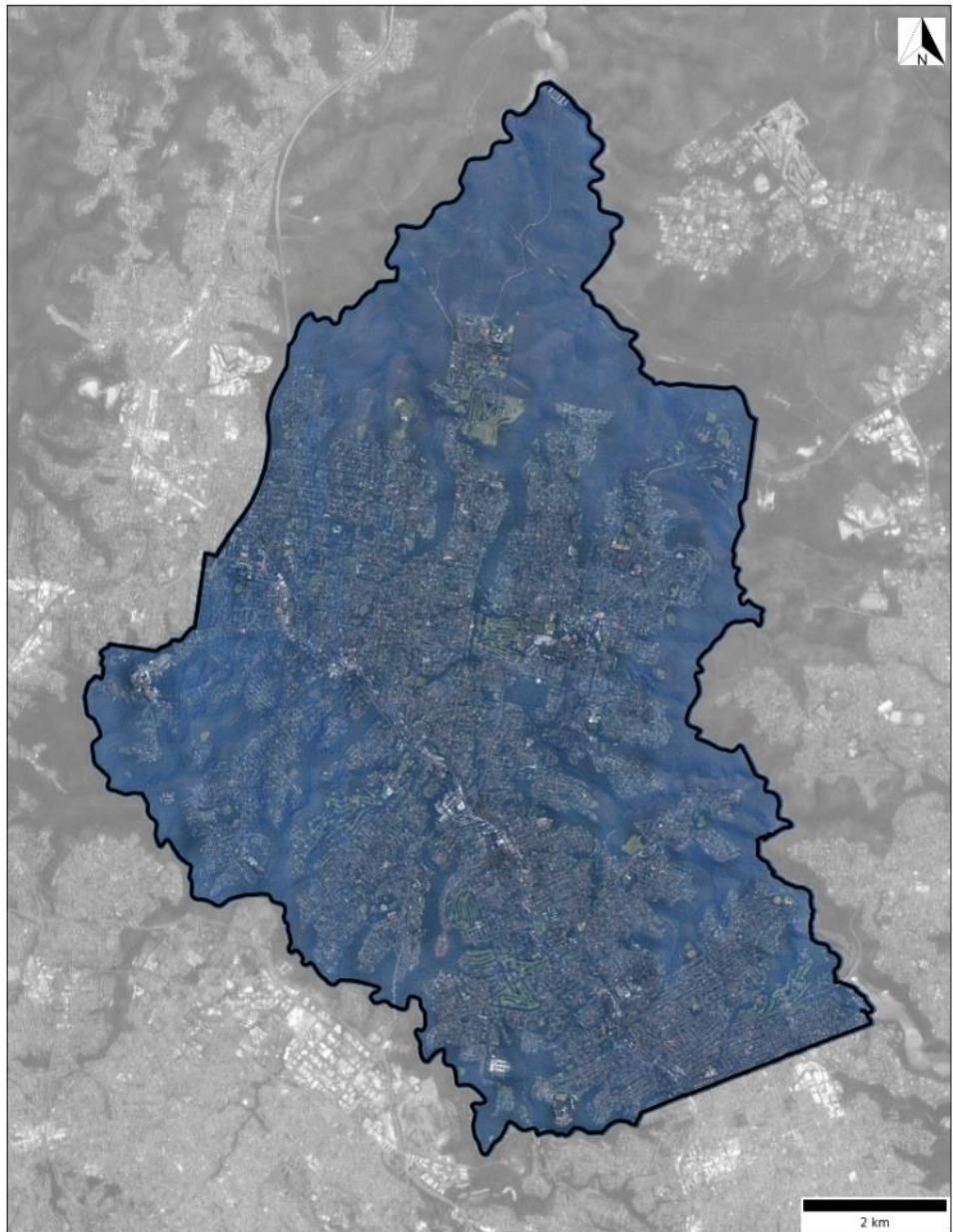


Figure 7: High resolution Red, Green and Blue (RGB) imagery of Ku-ring-gai Council.

The 7-band dataset (Figure 8) is illustrated by a 3-band subset of bands (NIR, red and green bands), known as a False Colour Composite (FCC). Vegetation is displayed as red pixels.

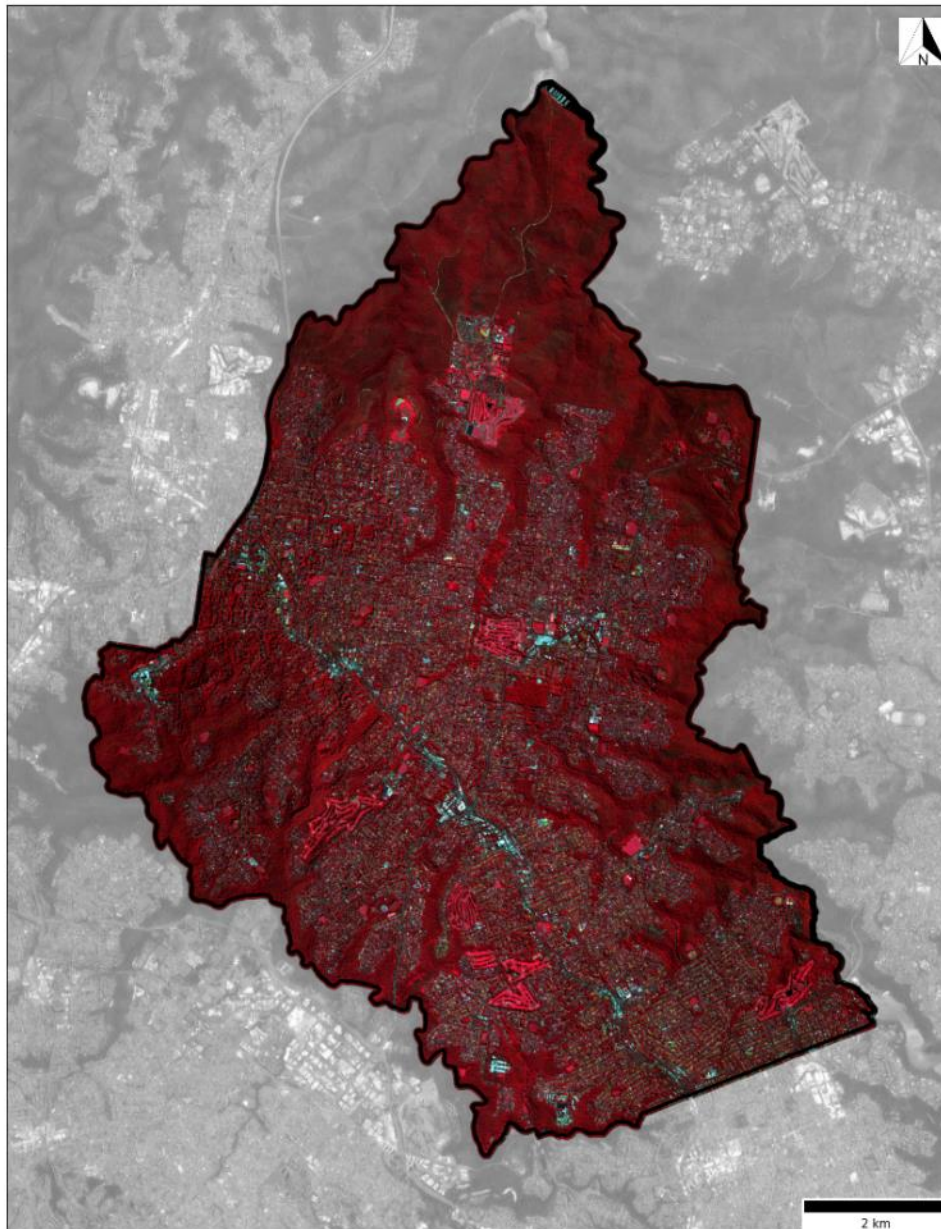


Figure 8: False colour composite (FCC) derived from the 7-band multispectral imagery, showing vegetation across Ku-ring-gai Council (red pixels).

The height-stratified vegetation cover dataset (Figure 9) consists of specific height strata as follows: blue (0-3m), light green (3-5m), medium-light green (5-10m), medium green (10-15m), medium-dark green (15-20m) and dark green (>20m).

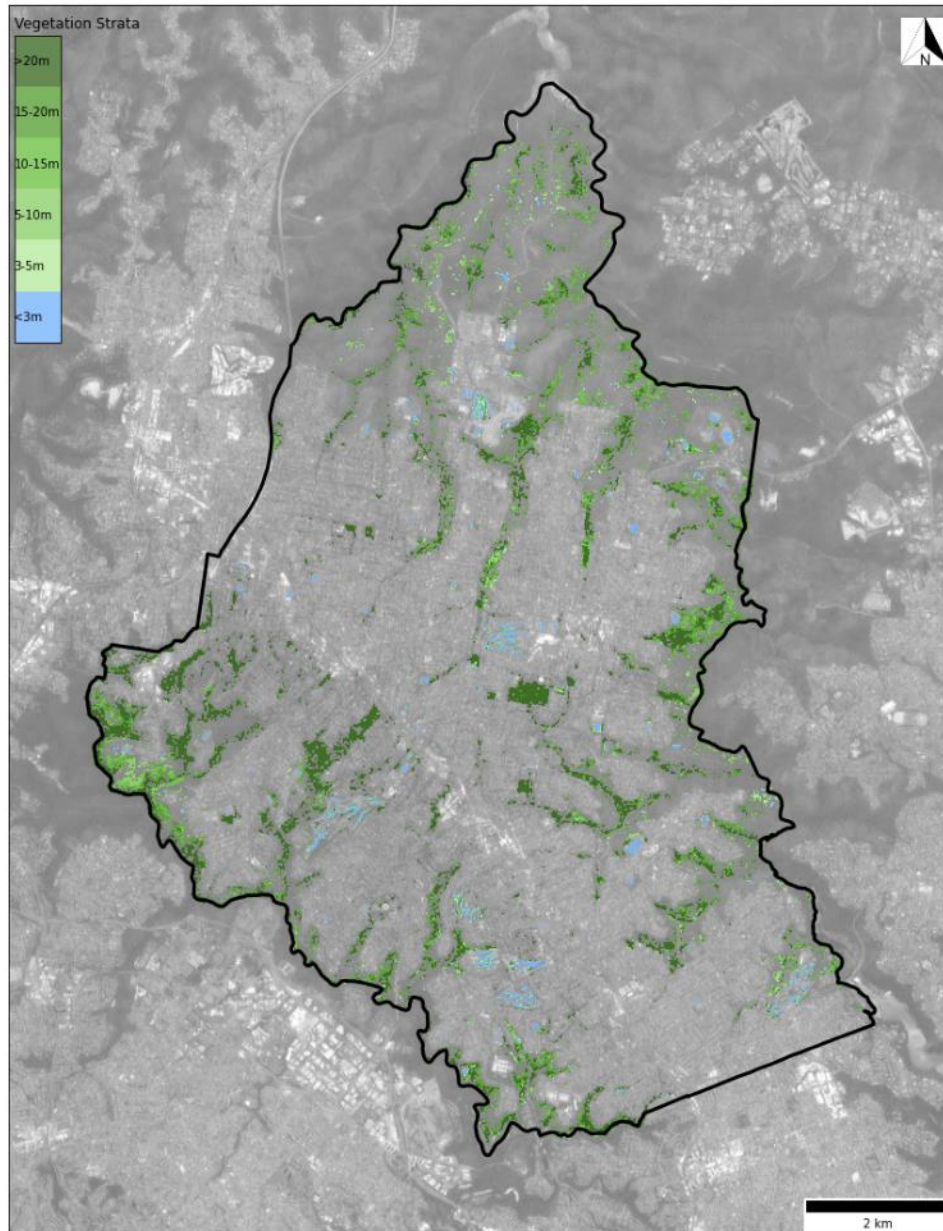


Figure 9: Height stratified vegetation dataset with each stratum displayed in a unique colour: blue (0-3m), light green (3-5m), medium-light green (5-10m), medium green (10-15m), medium-dark green (15-20m) and dark green (>20m). This legend is used for all images of this dataset throughout this report.

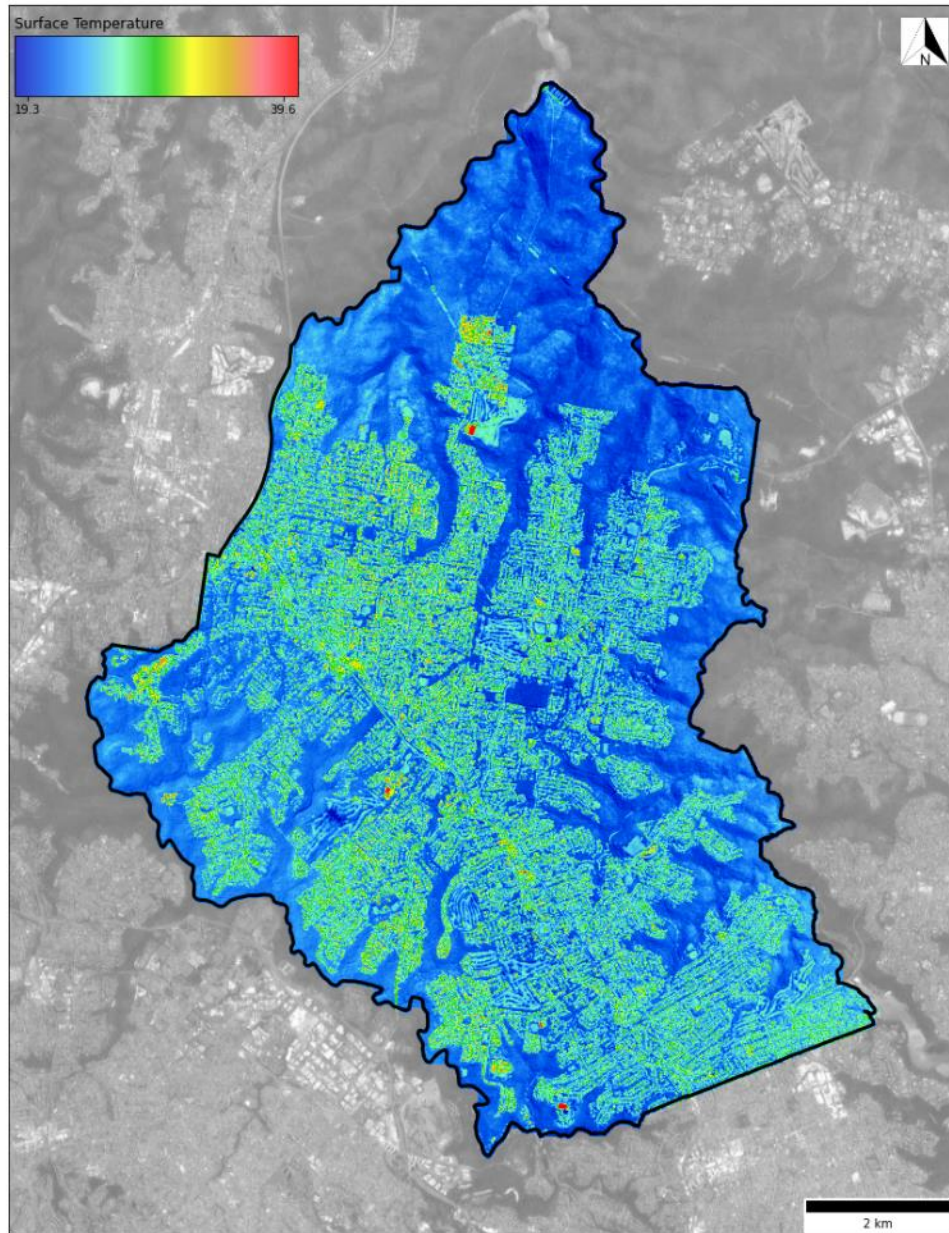


Figure 10: Radiometrically corrected thermal ortho land surface temperature of Ku-ring-gai Council ranging from 19.3°C (blue) to 39.6°C (red).

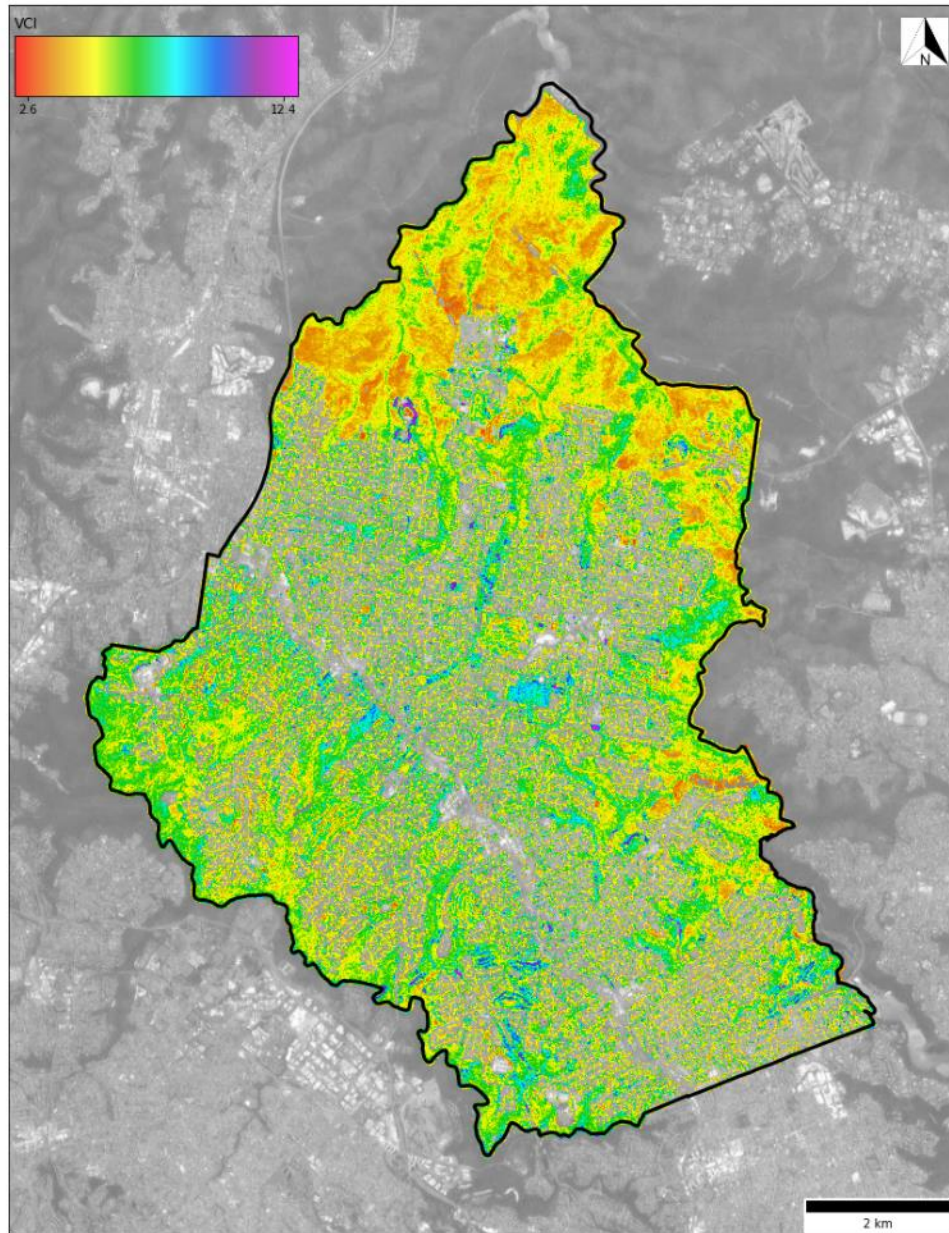


Figure 11: Vegetation Condition Index (VCI), with values ranging from low (red; 2.6) to high (magenta; 12.4).

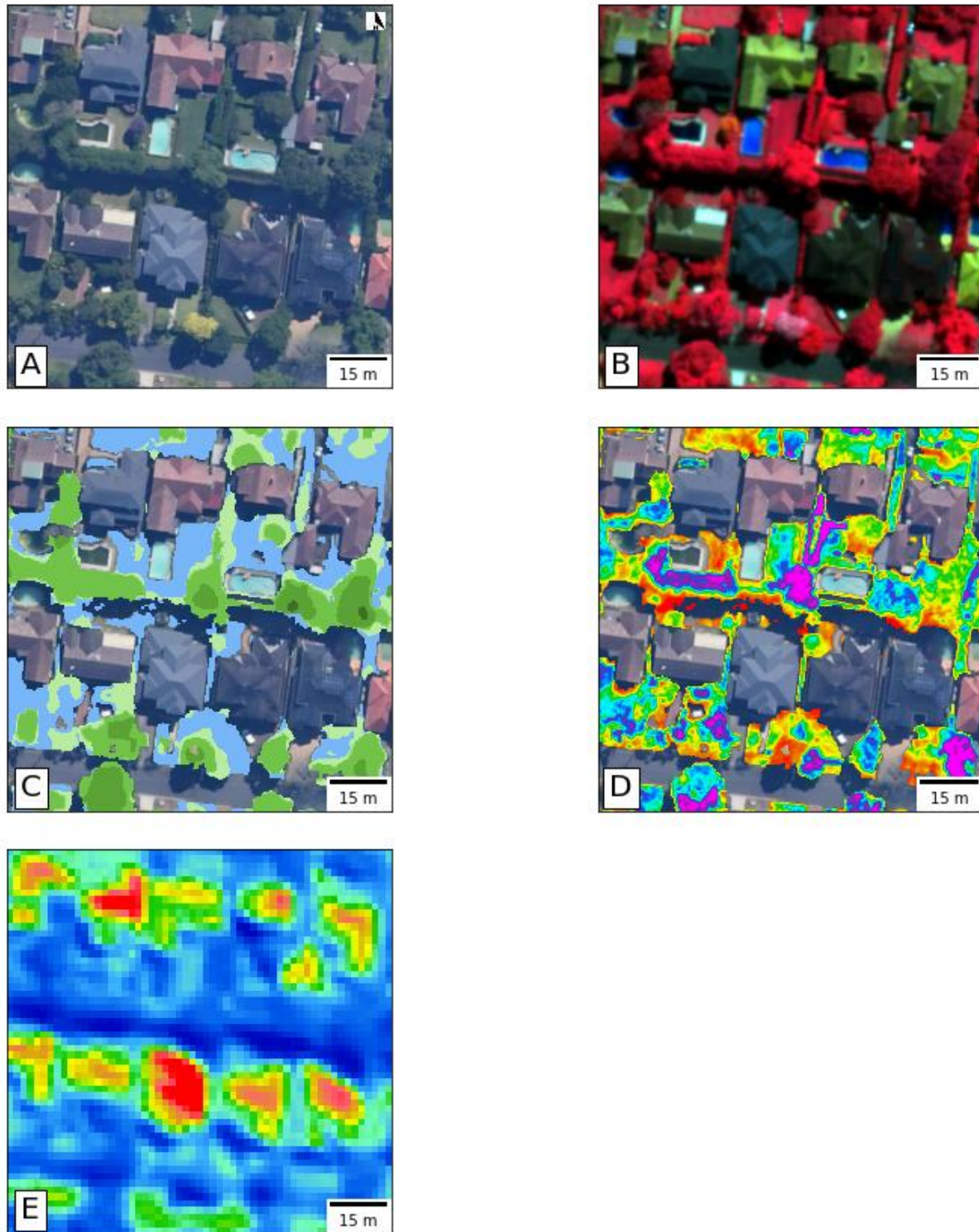


Figure 12: Close-up image of each dataset generated for Ku-ring-gai Council. A) High resolution 3-band RGB. B) False Colour Composite (FCC) showing vegetation in red, derived from the 7-band multispectral imagery. C) Height-stratified vegetation cover, with each stratum displayed as a different colour; blue (0-3m), light green (3-5m), medium-light green (5-10m), medium green (10-15m), medium-dark green (15-20m), and dark green (>20m). D) Vegetation Condition Index (VCI) used for the calculation of vegetation condition statistics and colour-scaled from low reflectance (red; 2.6) through to high reflectance (magenta; 12.4). E) Land Surface Temperature showing low temperatures (blue; 19.3 °C) and high (red, 39.6 °C).

3.1 Vegetation Cover

Height stratified vegetation cover was calculated for the urban boundary, each suburb, town centre, land use zone, land ownership, and the Council as a whole.

For this report, canopy is classified as vegetation 3m or more in height.

3.1.1 Council Wide

The Council has a total area of 8539.5 ha. Approximately two-thirds (68.9%) of the Council was covered by vegetation. The remaining 31.1% (2659.1 ha) was non-vegetated surfaces, such as buildings, roads, exposed soil and dead grass (Figure 13). Vegetation classified as less than 3m in height, including turf, grasses, groundcovers and shrubs, occupied 18.9% (1615.2 ha) of the total area. Canopy (vegetation 3m and above) covered 50% (4265.3 ha) of the Council.

Ku-Ring-Gai Council LGA

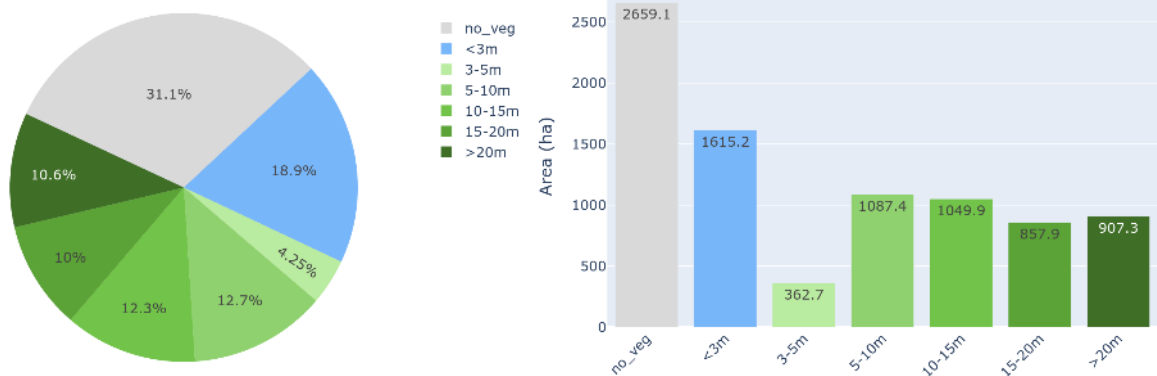


Figure 13: Land cover classification proportion (%) (left) and hectare coverage (right) of the entire Ku-ring-gai Council LGA boundary.

3.1.2 Urban Area

The urban boundary of the Council is defined as the total LGA except for land classified as C1 – National Parks. The urban boundary has a total area of 6789.6 ha. Nearly two-thirds (63.8%) of the urban boundary was covered by vegetation. The remaining 36.2% (2461 ha) were classified as non-vegetated surfaces (Figure 14). Vegetation classified as less than 3m in height occupied 20.2% (1368 ha) of the urban boundary. Canopy (vegetation 3m and above) covered 43.6% (2959.6 ha) of the urban boundary.

Ku-Ring-Gai Council Urban Boundary

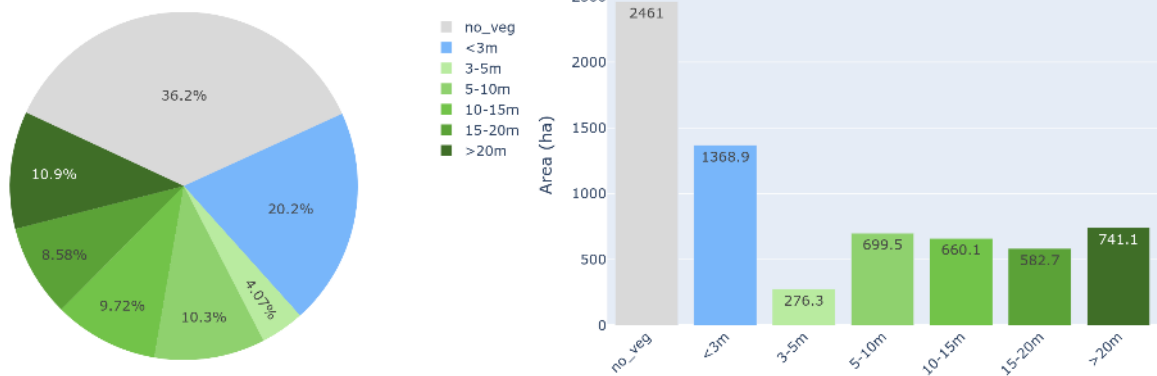


Figure 14: Land cover classification proportion (%) (left) and hectare coverage (right) of the Ku-ring-gai Council urban boundary.

3.1.3 Land Ownership

The LGA was classified by land ownership, excluding C1 (National Parks). The three ownership classification categories were ‘Private’, ‘Ku-ring-gai Council Owned’, and ‘Other’ (including Commonwealth and State managed land). The average canopy cover for land classified in the land ownership boundary was 43.6%. Council-owned land had the highest proportional canopy at 57.1% and land classified as ‘Other’ had 56.1% canopy cover. Private land had 34.9% proportional canopy cover.

Additionally, the canopy of each land ownership classification as a proportion of total canopy cover was calculated (Figure 16). Nearly half (48.6%) of the canopy is on privately owned land, and 43.3% is on Council owned land. The remaining 8.15% of the canopy is on land classified as ‘Other’.

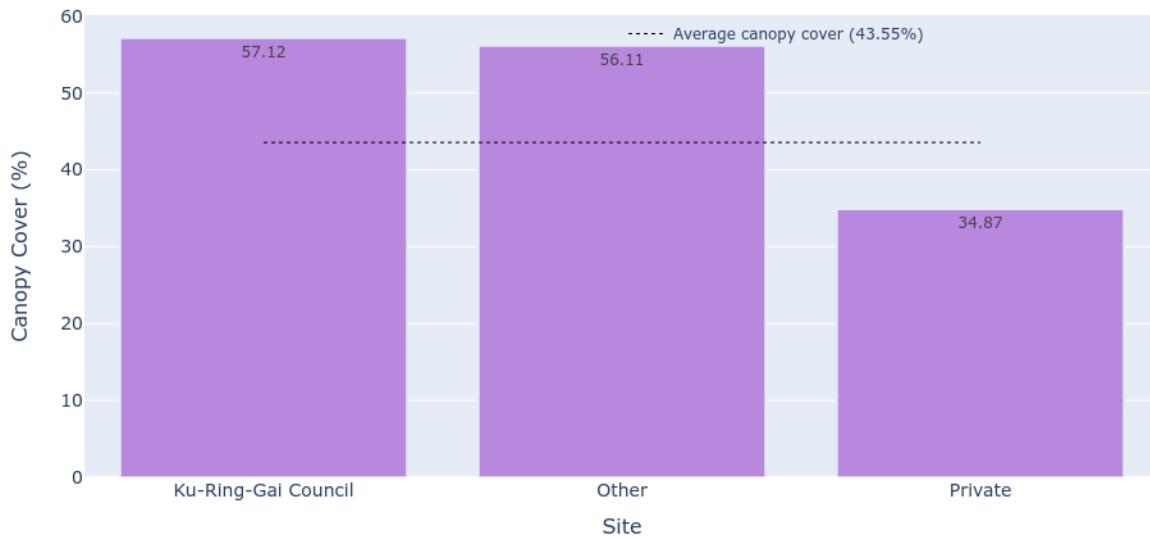


Figure 15: Proportional canopy cover of each land ownership category in Ku-ring-gai Council. The average canopy cover was 43.55%.

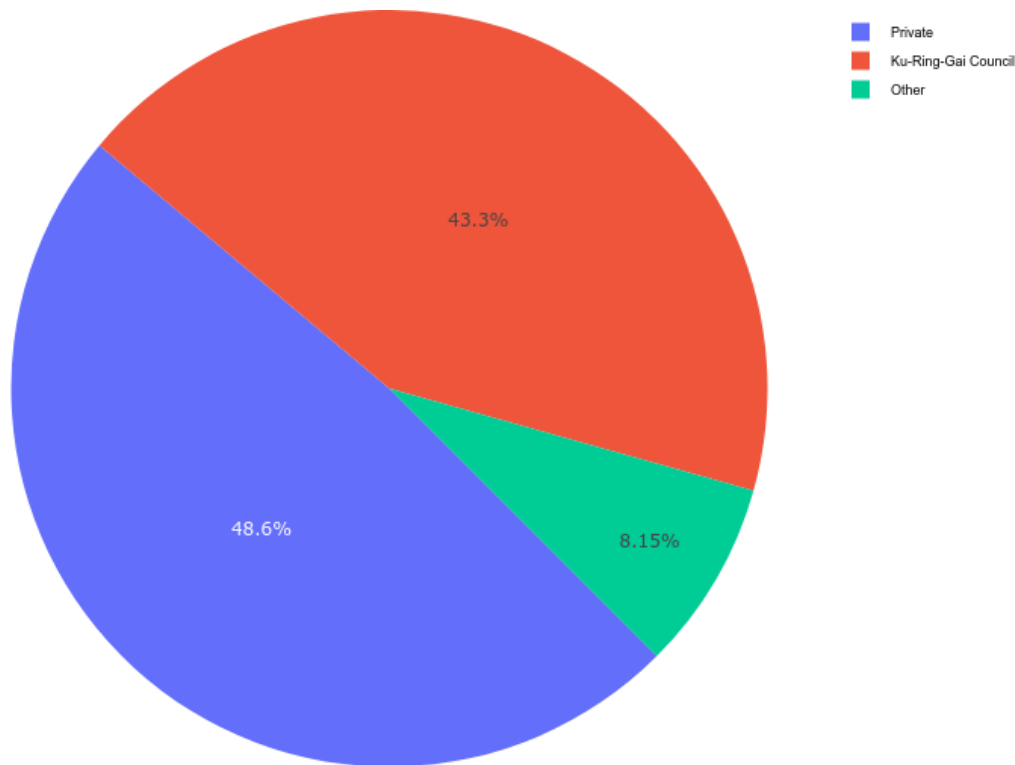


Figure 16: Canopy cover of each land ownership category in Ku-ring-gai Council as a proportion of total canopy cover (%).

3.1.4 Suburb (total LGA)

The average canopy cover for Ku-ring-gai Council was 50%. Canopy was calculated for each suburb within the entire LGA boundary. Canopy cover varied for each suburb.

North Turramurra had the highest proportional canopy cover, at 63.3% of its total area (Figure 17). South Turramurra had the second highest (61.3%), followed by St Ives Chase (59.8%).

Roseville had the lowest proportional canopy cover (33.1%), followed by Killara (36.1%) and East Lindfield (37.7%) (Figure 17).

Additionally, the canopy of each suburb as a proportion of total Council-wide canopy cover was calculated (Figure 18). North Turramurra and St Ives contributed the most towards canopy, at 17.3 and 17.2%, respectively. Wahroonga contained 9.6% of the Council’s total canopy cover. Warrawee and Roseville Chase contributed the least canopy to the Council’s total (1.3% each) followed by East Lindfield (2%) and Roseville (2.3%).

The percentage of canopy cover of each suburb is spatially presented in Figure 19 as a thematic map. Increasing green intensity in the map corresponds to increasing proportional canopy cover.

A breakdown of proportional land cover by vegetation strata for each suburb can be found in Appendix A.

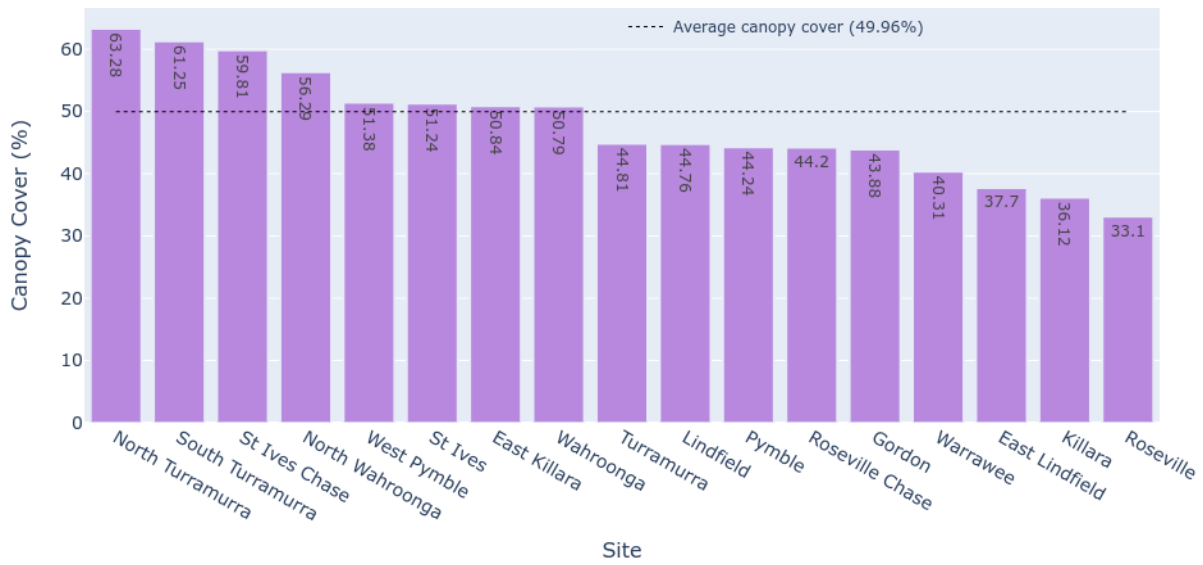


Figure 17: Proportional canopy cover of each suburb in Ku-ring-gai Council. The average canopy cover was 49.96%.

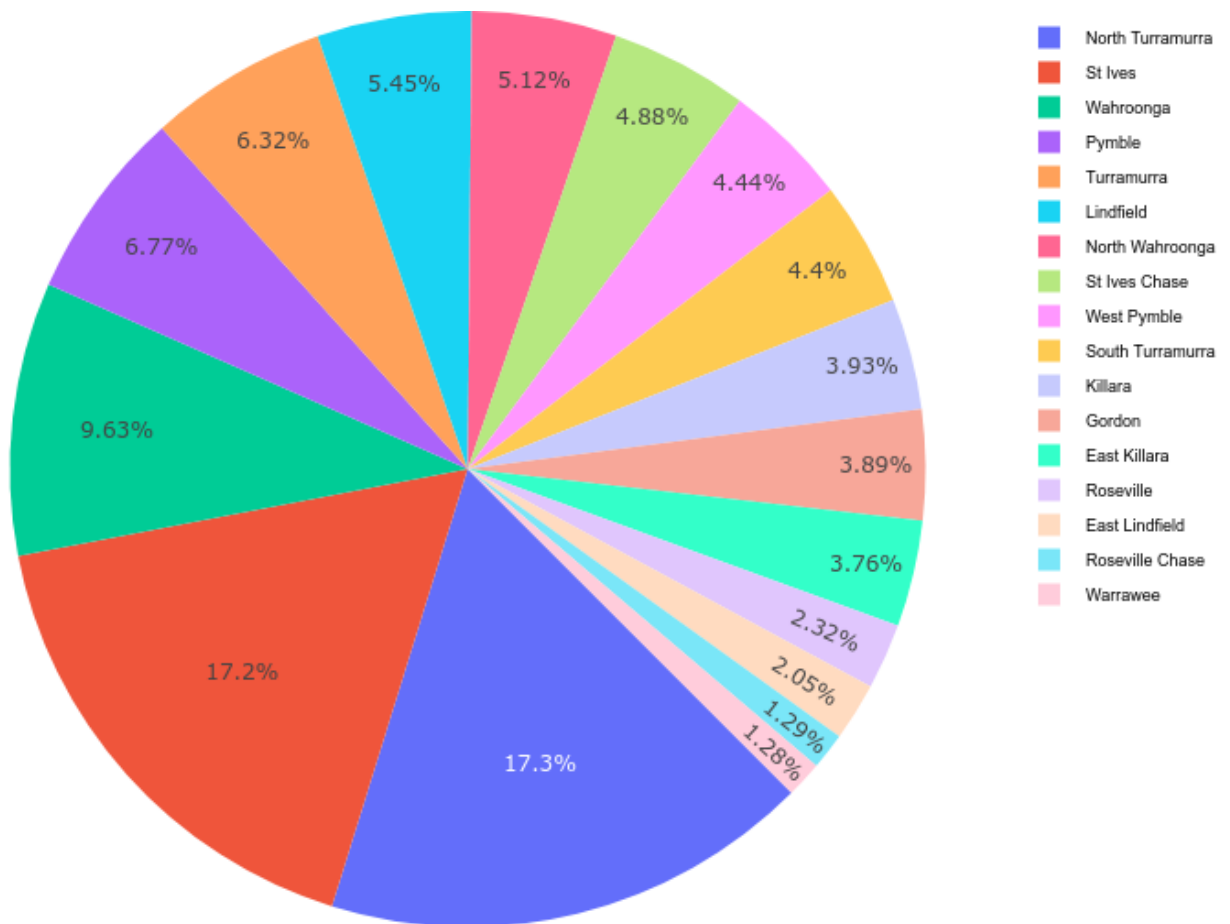


Figure 18: Canopy cover of each suburb in Ku-ring-gai Council as a proportion of total Council-wide canopy cover (%).

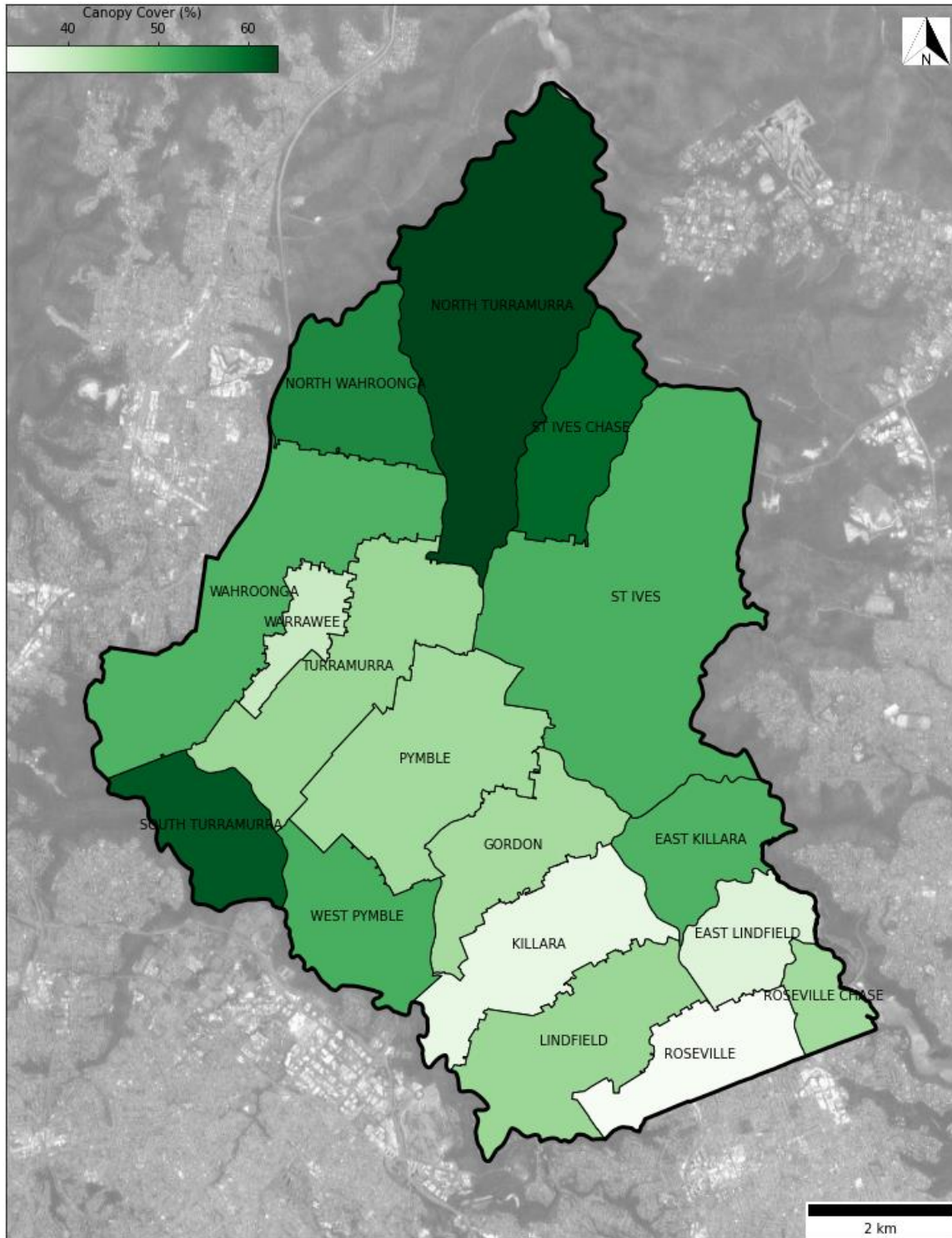


Figure 19: Thematic map showing canopy cover as a percentage of total suburb area. The darker green indicates a higher relative canopy cover percentage.

3.1.5 Suburb (urban boundary)

The average canopy cover for the **urban** area of Ku-ring-gai Council was 43.6%. The canopy was calculated for each suburb within the urban boundary. Canopy cover varied for each suburb.

South Turramurra had the highest proportional canopy cover, at 57.2% of its total area (Figure 20). North Turramurra had the second highest (51.7%), followed by Wahroonga (48.6%). Roseville had the lowest proportional canopy cover (33.1%), followed by Killara (34.3%) and East Lindfield (36.3%).

Additionally, the canopy of each suburb as a proportion of total urban canopy cover was calculated (Figure 21). St Ives contributed the most towards canopy (15.4%) followed by Wahroonga (12.8%). Warrawee and Roseville Chase contributed the least canopy to the Council’s total (1.8 and 1.9%, respectively) followed by East Lindfield (2.5%) and East Killara (3%).

The percentage of canopy cover for each suburb (urban) is spatially presented in Figure 22 as a thematic map. Increasing green intensity in the map corresponds to increasing proportional canopy cover.

A breakdown of proportional land cover by vegetation strata for each suburb (urban) can be found in Appendix B.

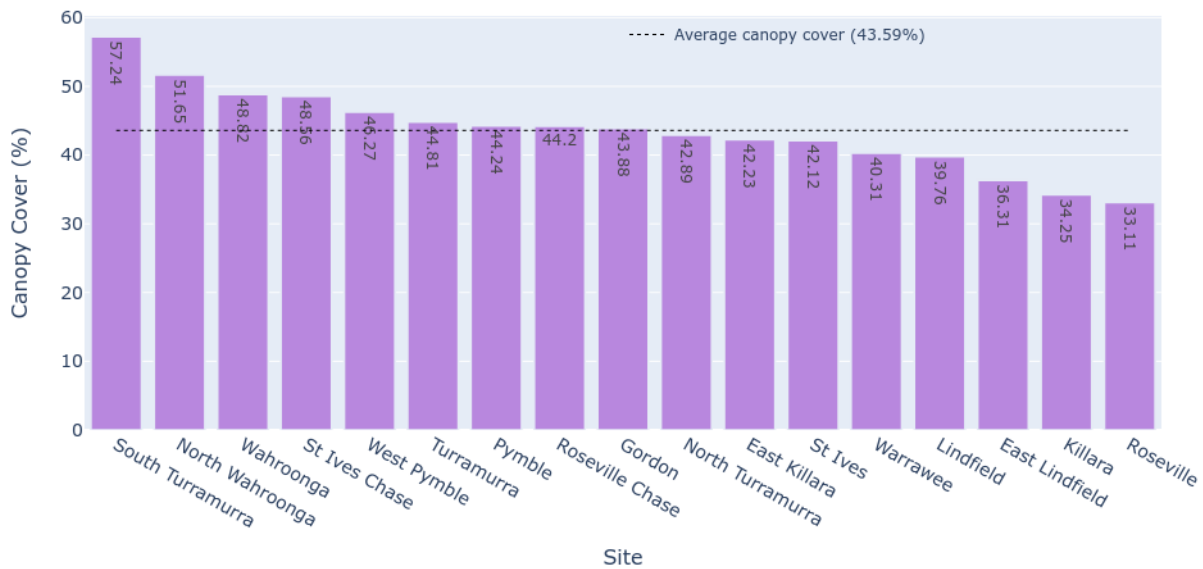


Figure 20: Proportional canopy cover of each suburb in the Ku-ring-gai Council urban area. The average canopy cover was 43.59%.

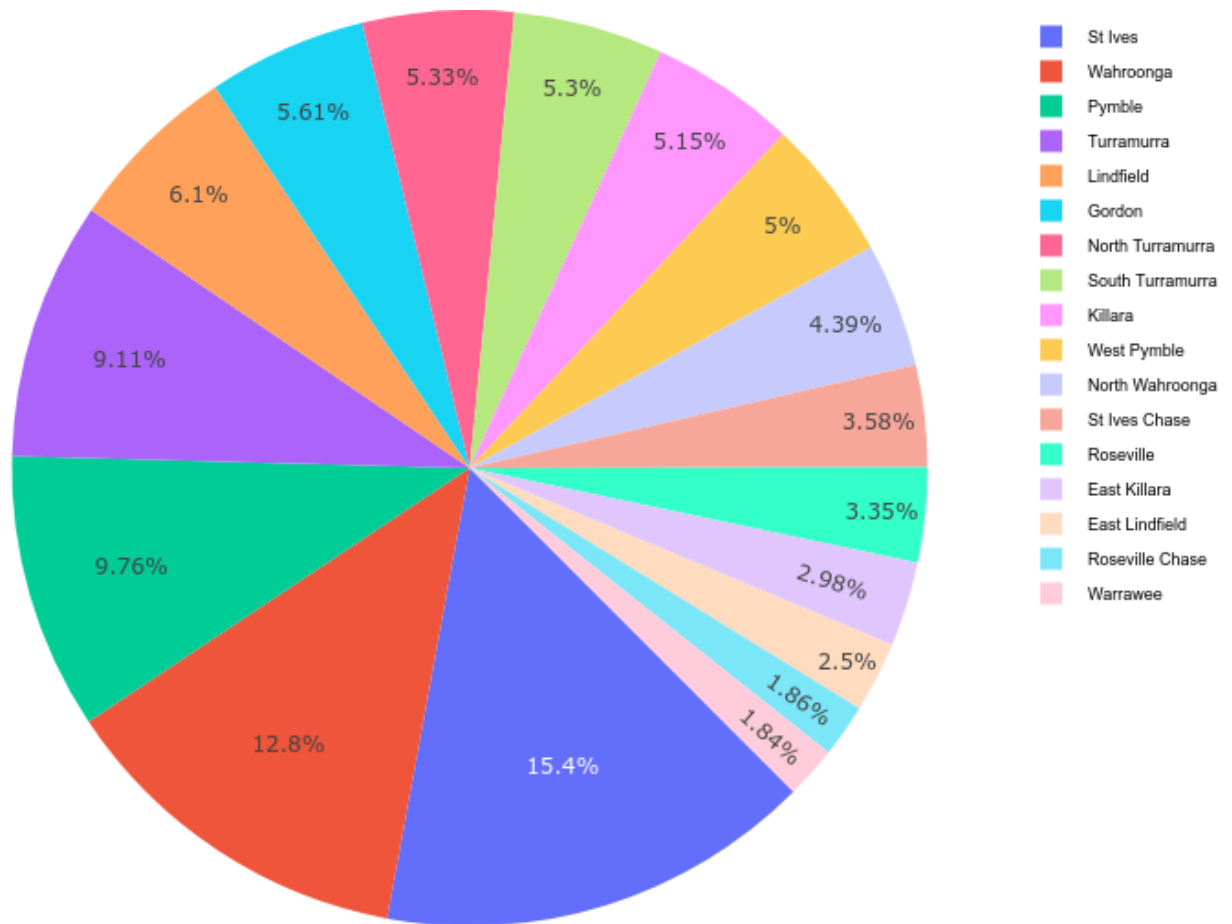


Figure 21: Canopy cover of each suburb in Ku-ring-gai Council as a proportion of urban canopy cover (%).

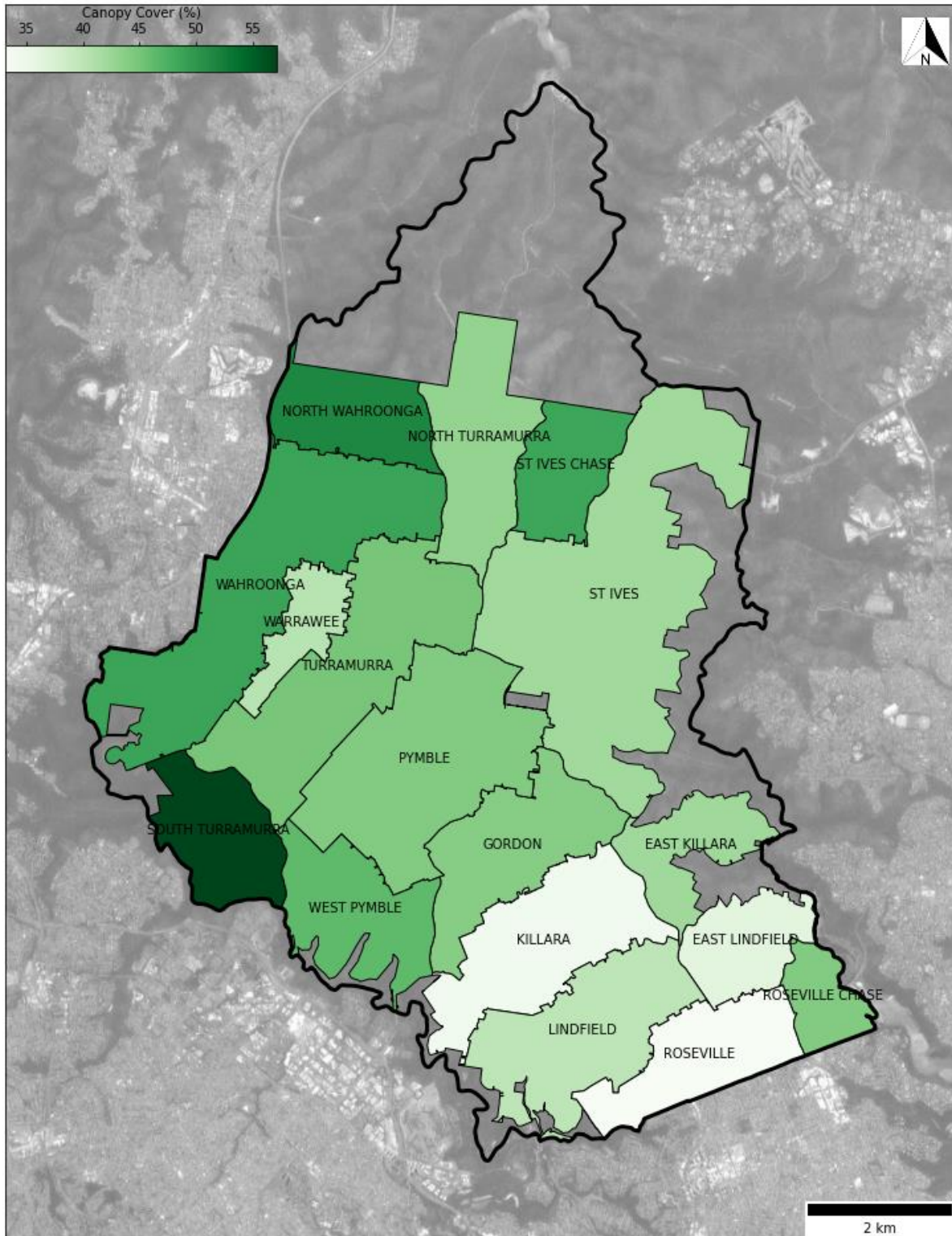


Figure 22: Thematic map showing canopy cover as a percentage of total urban suburb area. The darker green indicates a higher relative canopy cover percentage.

3.1.6 Town Centres

Canopy cover varied for each Town Centre.

Turrumurra Town Centre had the highest proportional canopy cover, at 41.9% of its total area, followed by Pymble Town Centre (39.2%) (Figure 23). Roseville Town Centre had the lowest proportional canopy cover (31.6%). Lindfield, St Ives, Gordon and Killara Town Centres all had similar canopy cover, between 32 and 33%.

Additionally, the canopy of each ward as a proportion of total Town Centre canopy cover was calculated (Figure 24). Turrumurra Town Centre contributed 22.3%, followed by St Ives (17.1%). Roseville contributed the least canopy to the total (6.2%) followed by Killara (6.3%).

The percentage of canopy cover in each Town Centre is spatially presented in Figure 25 as a thematic map. Increasing green intensity in the map corresponds to increasing proportional canopy cover.

A breakdown of proportional land cover by vegetation strata for each Town Centre can be found in Appendix C.

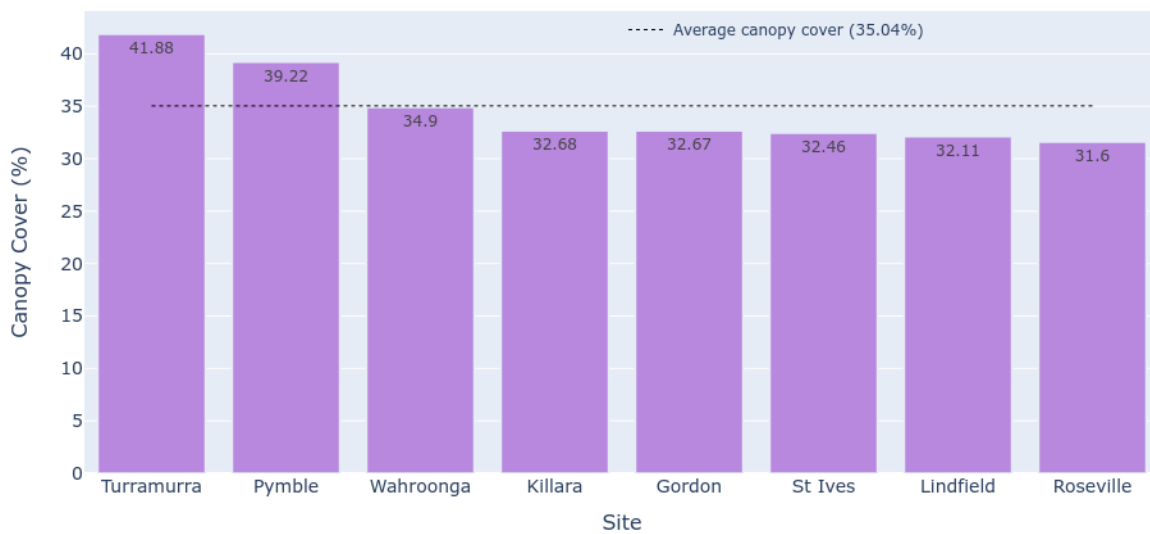


Figure 23: Proportional canopy cover of each Town Centre in Ku-ring-gai Council. The average canopy cover was 35.04%.

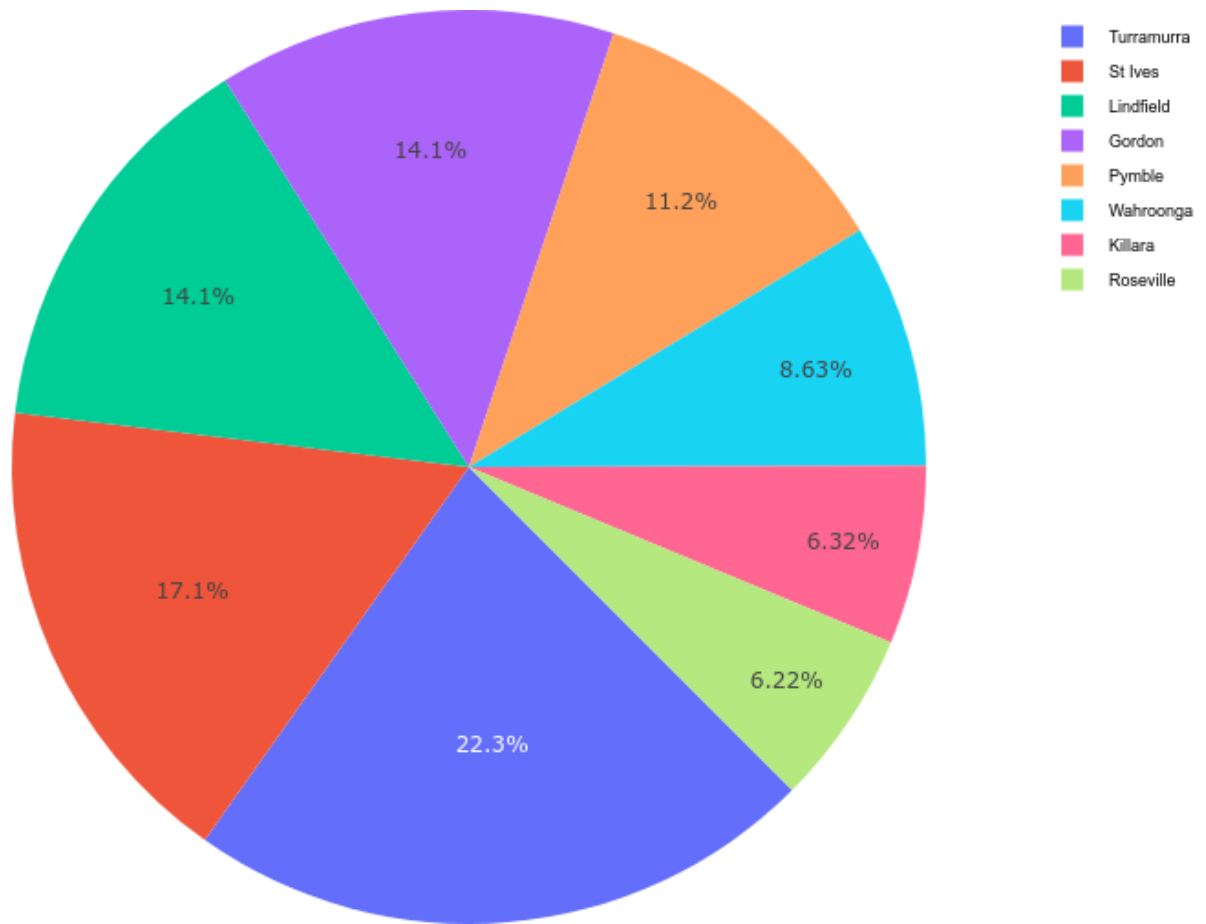


Figure 24: Canopy cover of each Town Centre in Ku-ring-gai Council as a proportion of total Town Centre canopy cover (%).

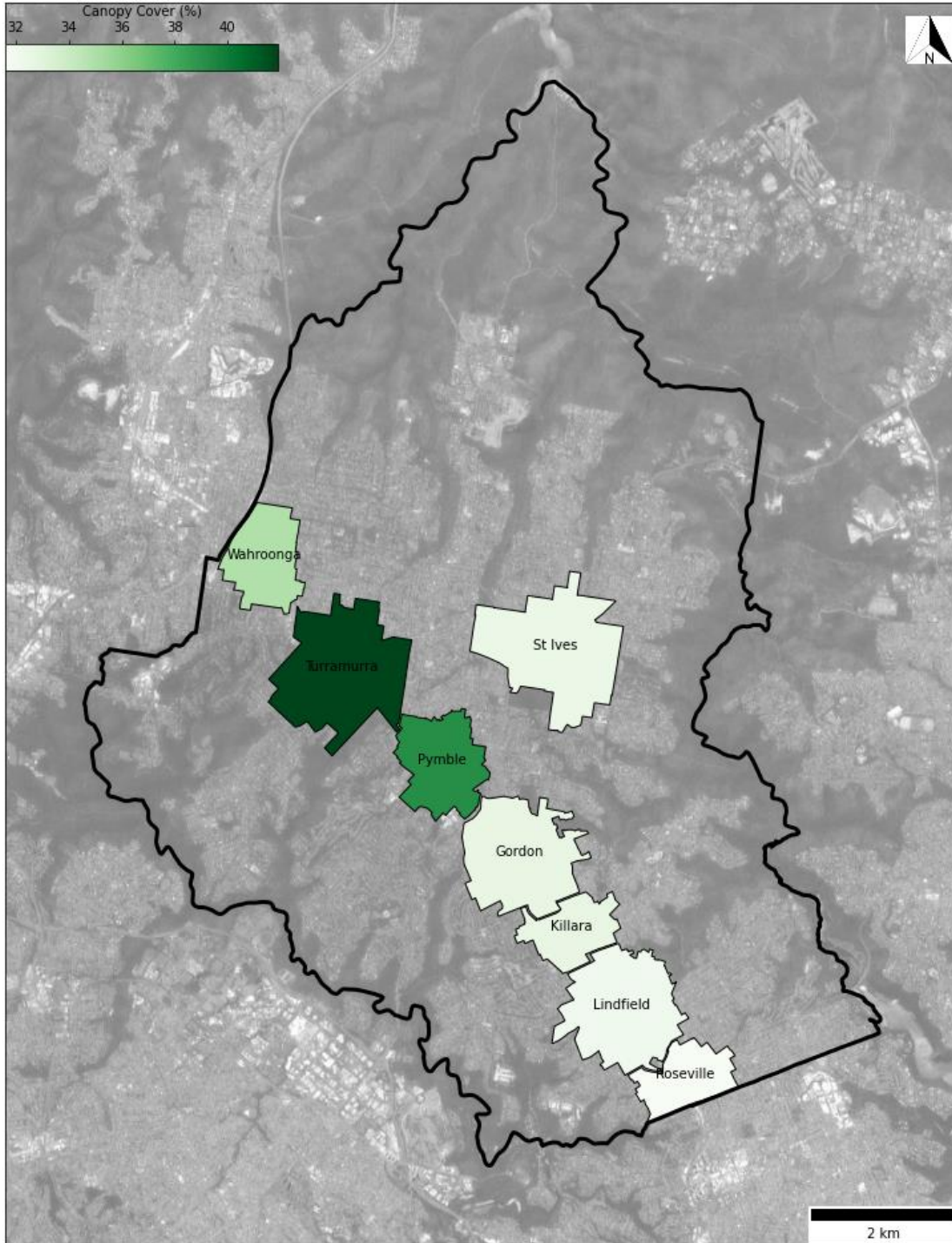


Figure 25: Thematic map showing canopy cover as a percentage of total Town Centre area. The darker green indicates a higher relative canopy cover percentage.

3.1.7 Land Use Zone

The average canopy cover for Ku-ring-gai Council was 50%. Canopy cover varied for each land use zone.

Land classified as E2 (Environmental Conservation) had the highest proportional canopy cover, at 83% of its total area (Figure 26), followed by E1 (National Parks) (74.7%).

B4 (Mixed Use) had the lowest proportional canopy cover (12.3%), followed by B2 (Local Centre) (15%) and B5 (Business Development) (20%).

Additionally, the canopy of each Land Use Zone as a proportion of total Council-wide canopy cover was calculated (Figure 27). E1 (National Parks) contributed the most towards canopy (30.6%), followed by R2 (Low Density Residential) and E2 (Environmental Conservation) at 27.4 and 24.3%, respectively.

The percentage of canopy cover in each Land Use Zone is spatially presented as a thematic map in Figure 28. Increasing green intensity in the map corresponds to increasing proportional canopy cover.

A breakdown of proportional land cover by vegetation strata for each Land Use Zone can be found in Appendix D.

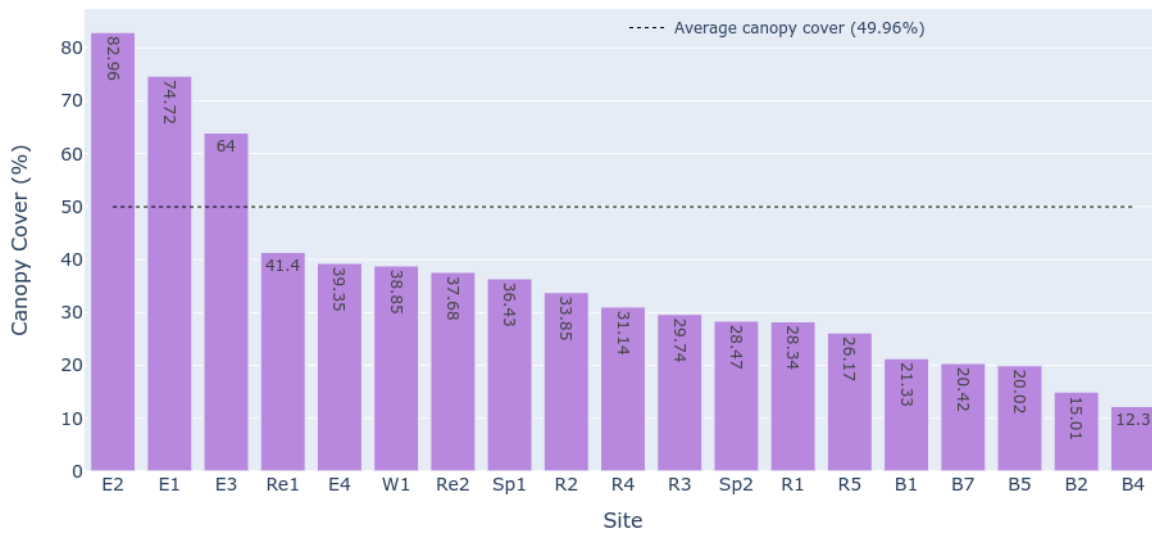


Figure 26: Proportional canopy cover of each Land Use Zone in Ku-ring-gai Council. The average canopy cover was 49.96%.

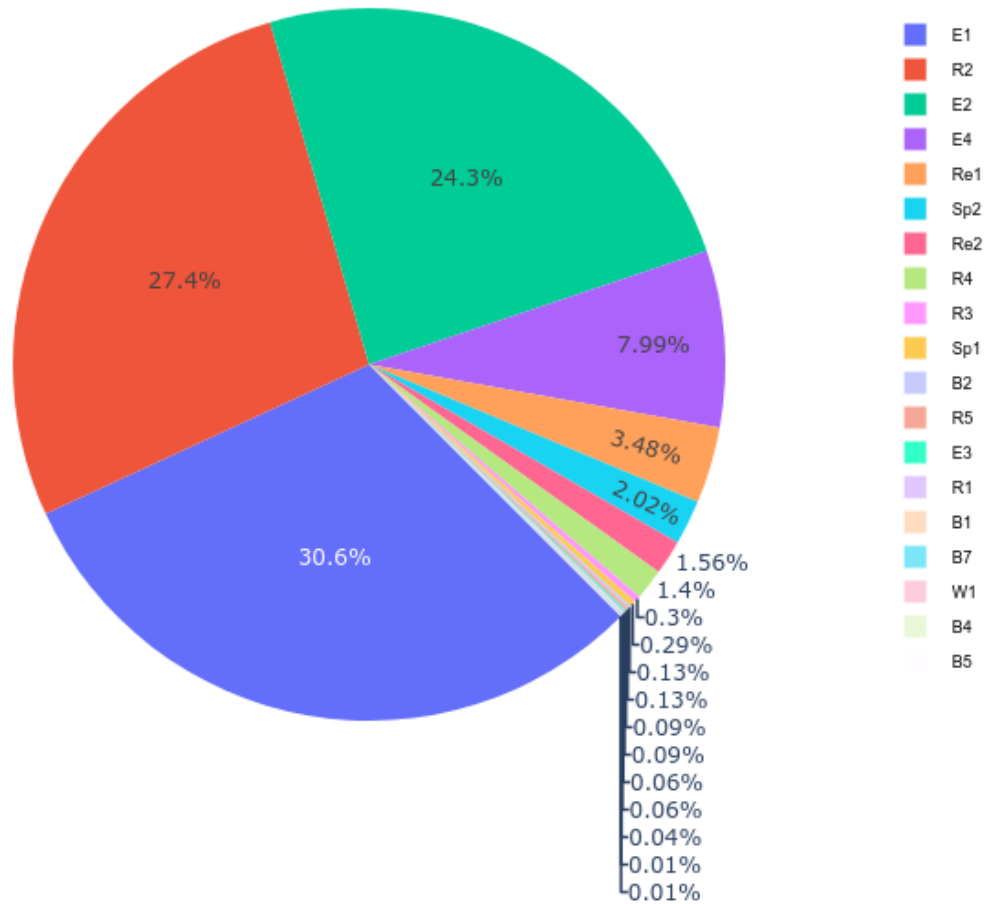


Figure 27: Canopy cover of each Land Use Zone in Ku-ring-gai Council as a proportion of total Council-wide canopy cover (%).

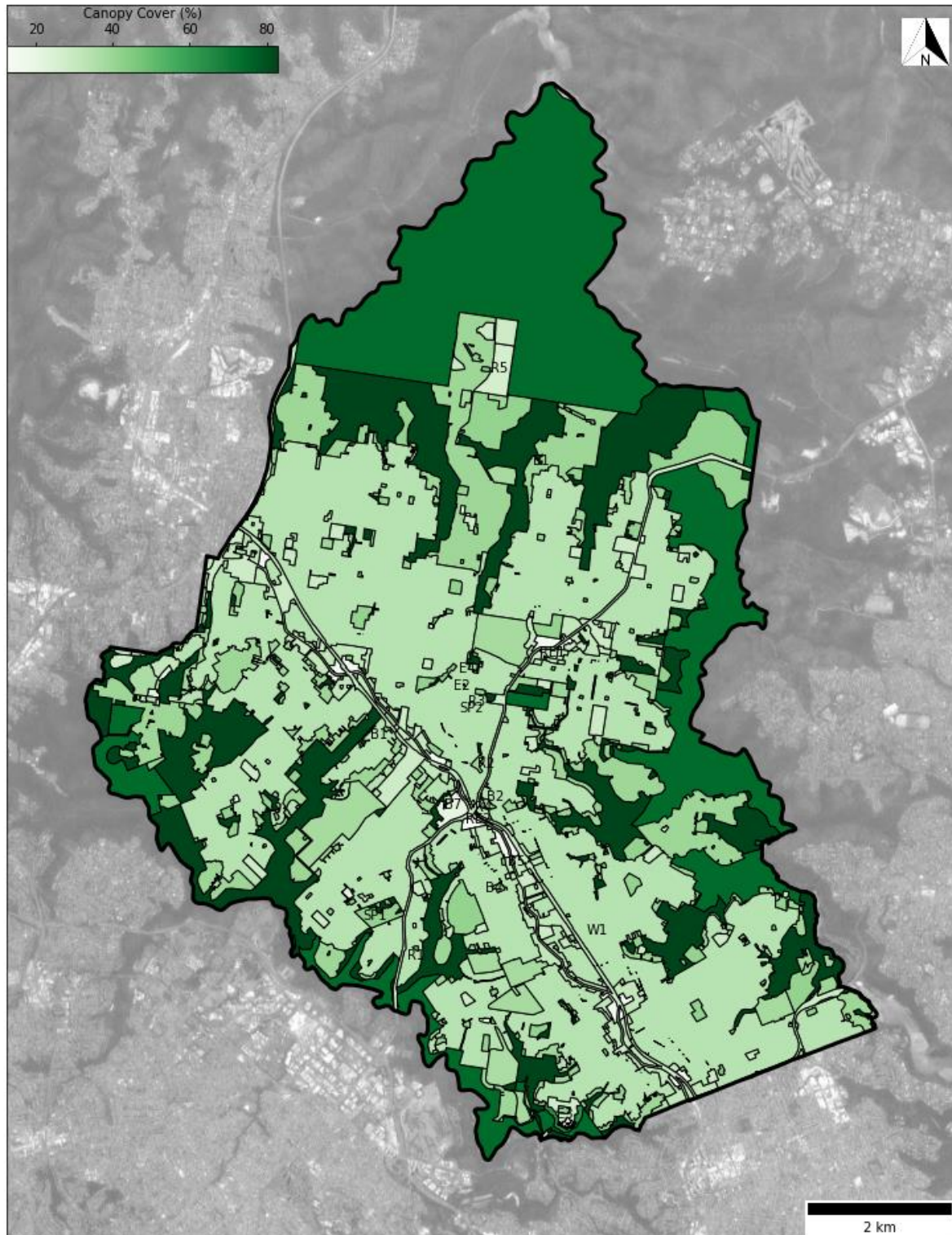


Figure 28: Thematic map showing canopy cover as a percentage of total Land Use Zone area. The darker green indicates a higher relative canopy cover percentage.

3.1.8 Road Reserves

Road reserves have a total area of 987.7 ha. Over half (52.5%, 518.9 ha) of the road reserve area is vegetated. The remaining 47.5% were not vegetated surfaces (Figure 29). Vegetation classified less than 3m in height made up 17% (168.2 ha) of road reserves. Canopy (vegetation 3m and above) covered 35.5% (350.7 ha) of road reserves.

Ku-Ring-Gai Council Roads

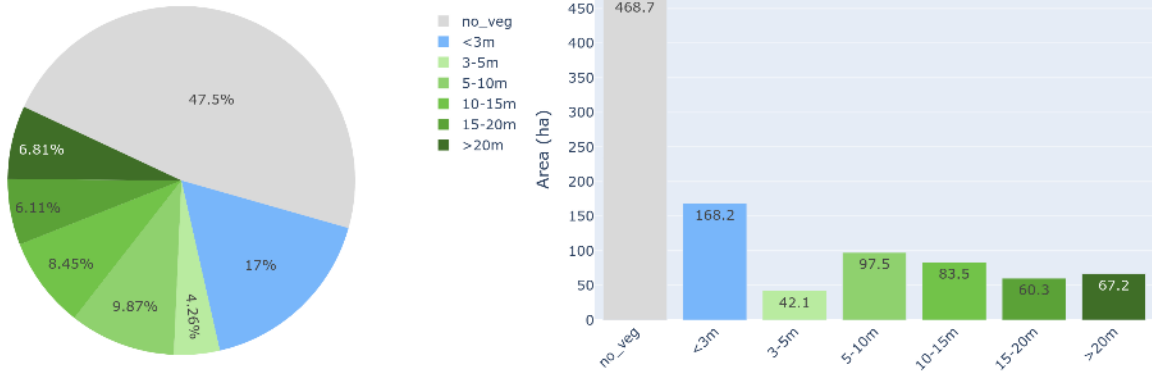


Figure 29: Land cover classification proportion (%) (left) and hectare coverage (right) of road reserves within Ku-ring-gai Council.

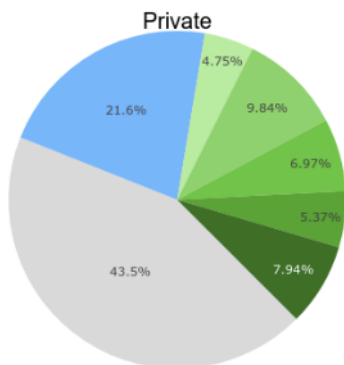
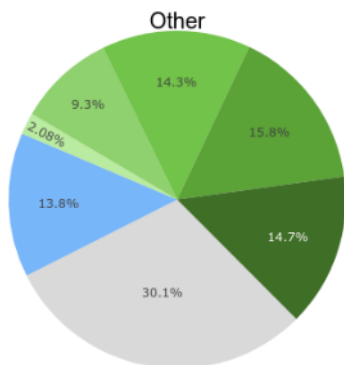
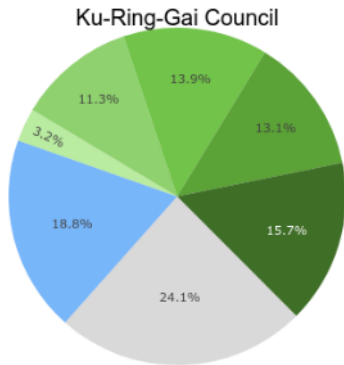
4 Conclusion

This study provides an accurate assessment of vegetation cover of Ku-ring-gai Council.

The main findings of this report are:

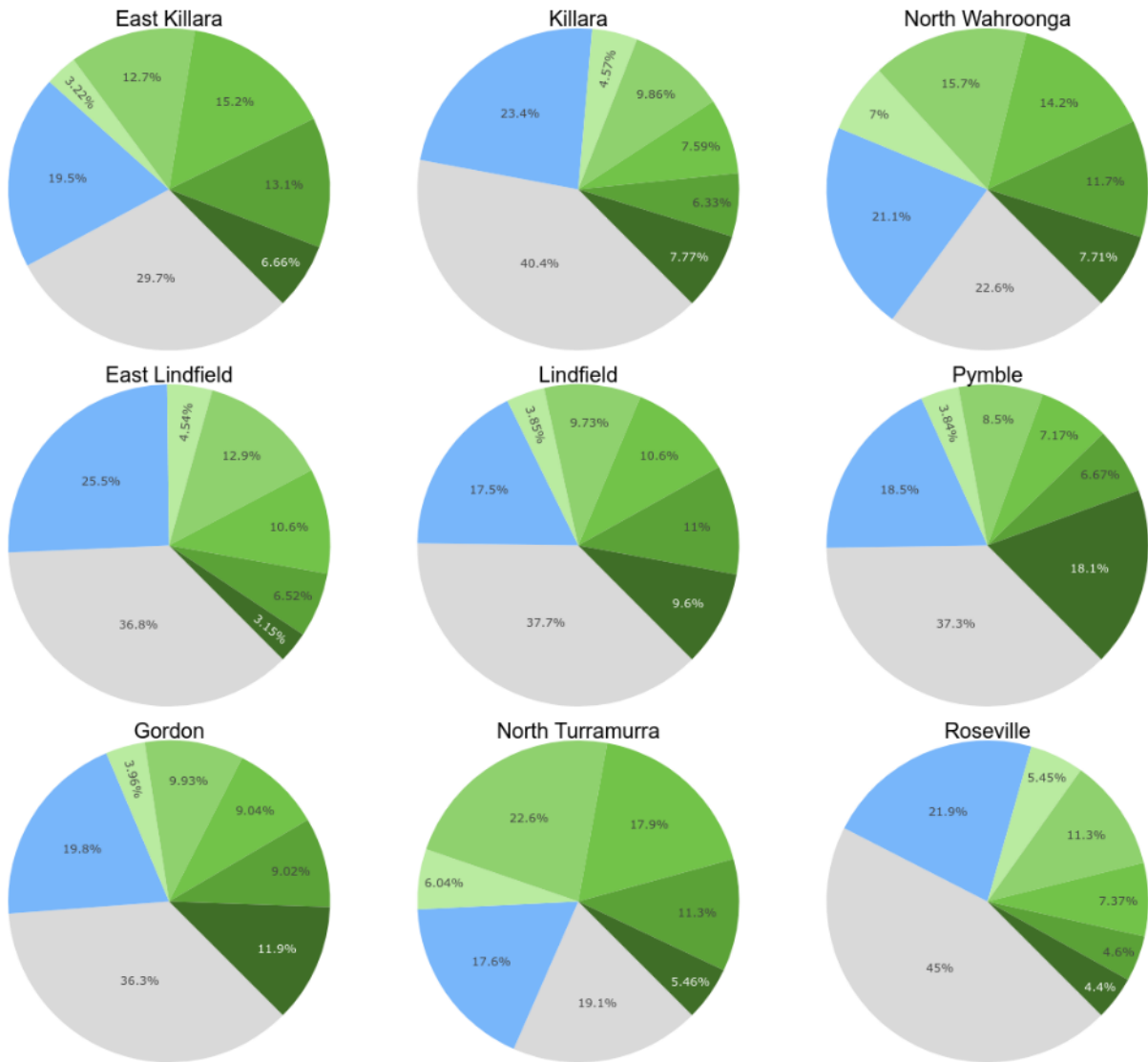
- The total vegetation cover in Ku-ring-gai Council was 68.9% (5880.4 ha) of the total LGA area of 8539.5 ha.
- Canopy (vegetation 3m and above) covered 50% (4265.3 ha) of the Council.
- The total vegetation cover of the urban area of Ku-ring-gai Council was 63.8% (4328.5 ha).
- Canopy covered 43.6% (2959.6 ha) of the urban area.
- Ku-ring-gai Council-owned land had the highest proportional canopy at 57.1%, and land classified as 'Other' had 56.1% canopy cover. Private land had 34.9% proportional canopy cover.
- In terms of contribution to overall canopy cover (excluding C1), private land contributed 48.6%, Council owned land contributed 43.3%, and land classified as 'other' contributed 8.2%.
- North Turramurra had the greatest canopy cover as a proportion of suburb area (63.3%), while Roseville had the least (33.1%). In terms of overall Council canopy, North Turramurra contributed the most (17.3%) while Warrawee contributed the least (1.3%).
- Regarding urban area only, South Turramurra had the greatest canopy cover as a proportion of suburb area (57.2%), while Roseville had the least (33.1%). Regarding contribution to overall canopy cover in the urban area, St Ives contributed the most (15.4%) while Warrawee contributed the least (1.8%).
- In terms of Town Centres, Turramurra Town Centre had the greatest canopy cover as a proportion of its area (41.9%), while Roseville Town Centre had the least (31.6%). In terms of contribution to the overall canopy cover of Town Centres, Turramurra Town Centre contributed the most (22.3%) while Roseville Town Centre contributed the least (6.2%).
- Land classified as E2 (Environmental Conservation) had the highest proportional canopy cover, at 83% of its total area, while land classified as B4 (Mixed Use) had the lowest proportional canopy cover (12.3%). In terms of contribution to the overall canopy cover of the LGA, E1 (National Parks) contributed the most towards the canopy (30.6%), followed by R2 (Low Density Residential) and E2 (Environmental Conservation) at 27.4 and 24.3%, respectively.
- Overall, the canopy cover of road reserves was 35.5%.

Appendix A – Land Cover by Land Ownership

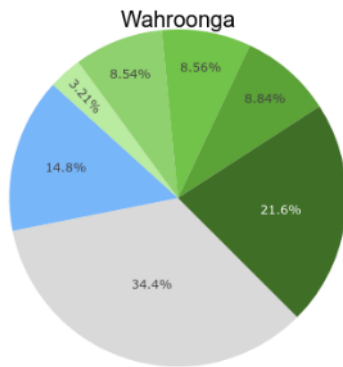
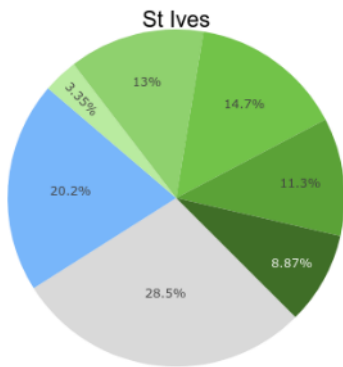
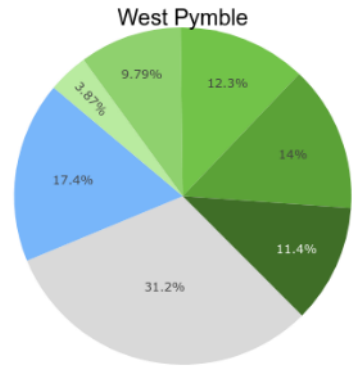
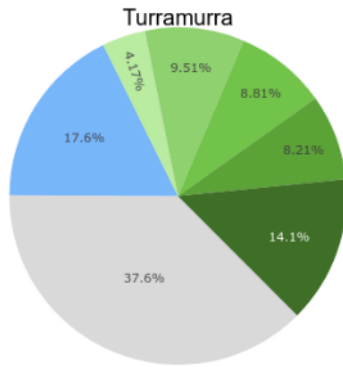
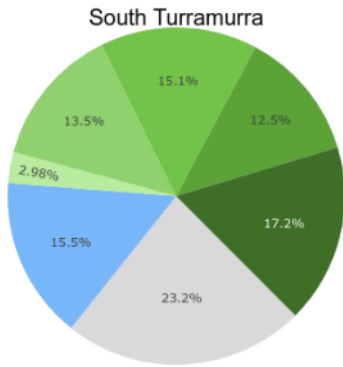
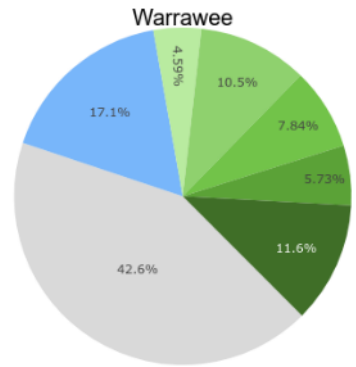
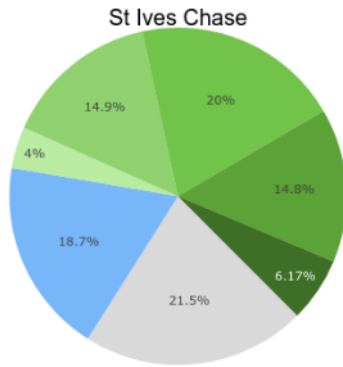
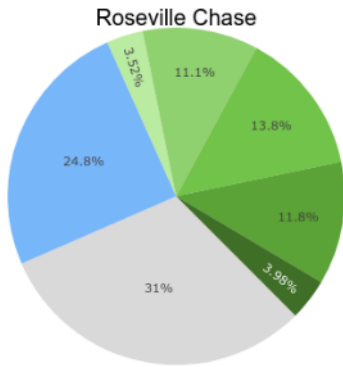


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Appendix B – Land Cover by Suburb (total LGA)

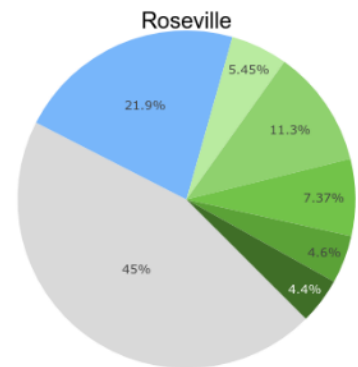
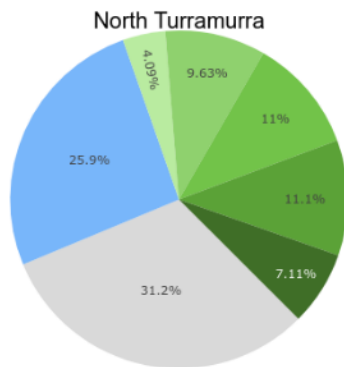
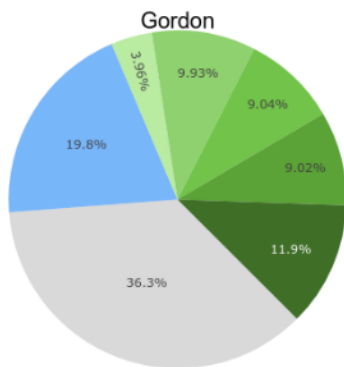
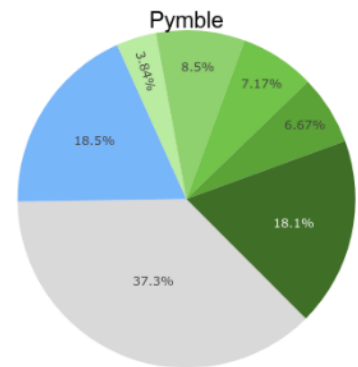
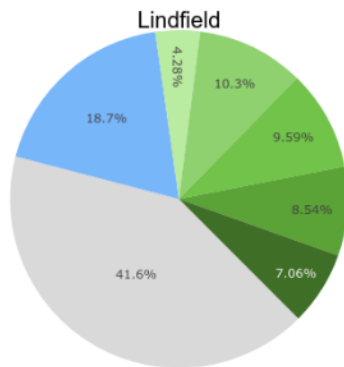
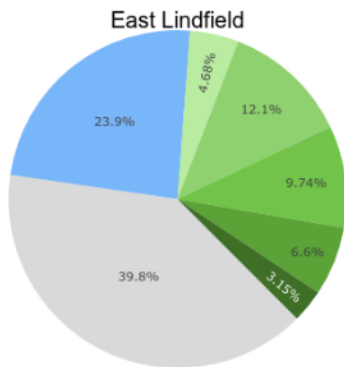
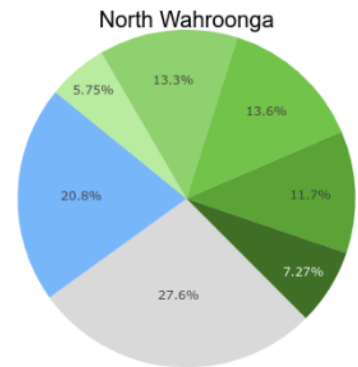
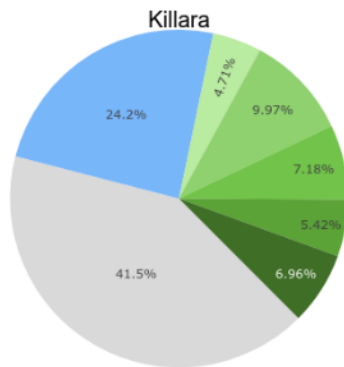
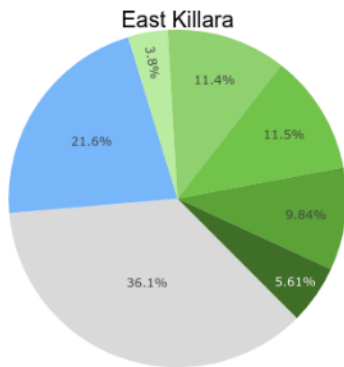


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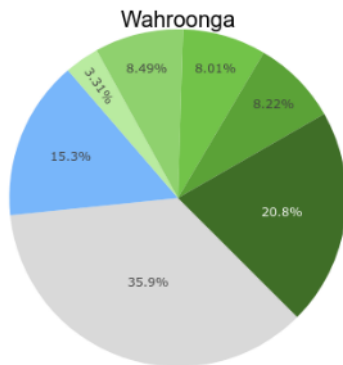
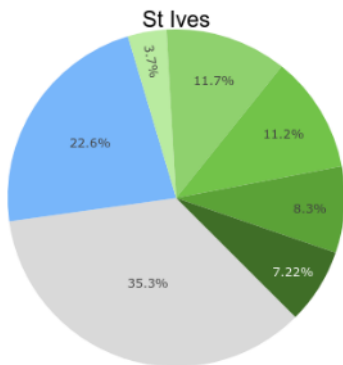
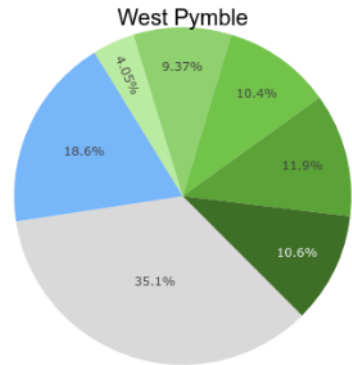
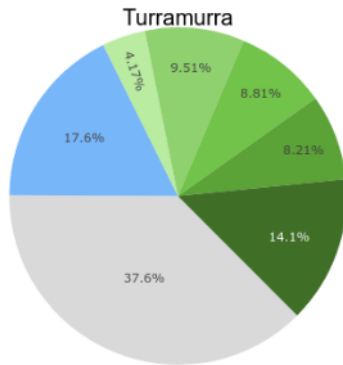
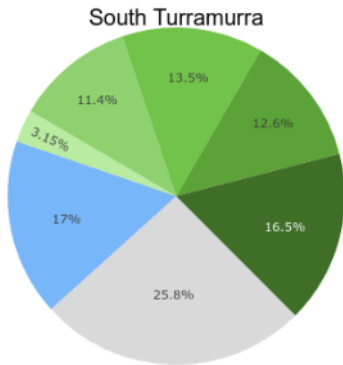
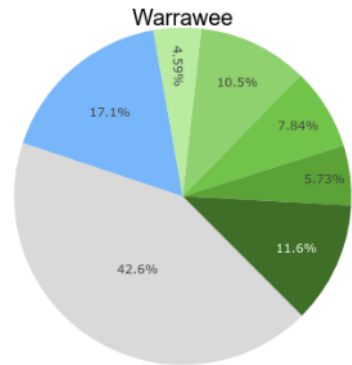
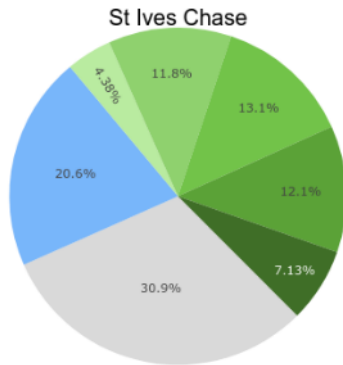
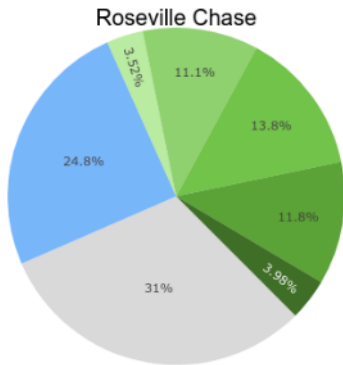


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Appendix C – Land Cover by Suburb (urban boundary)

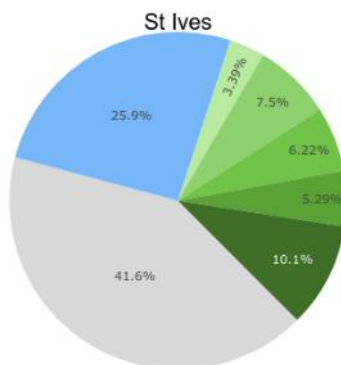
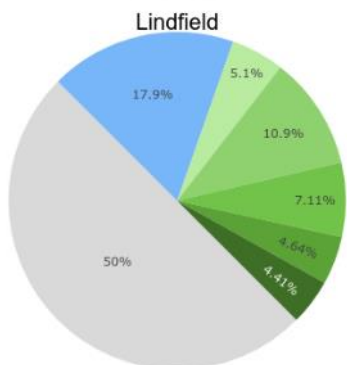
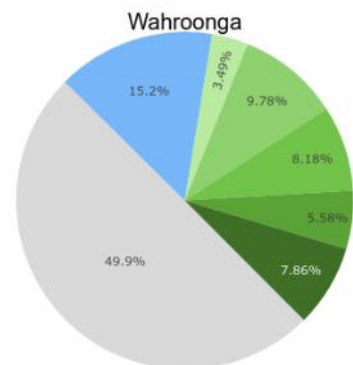
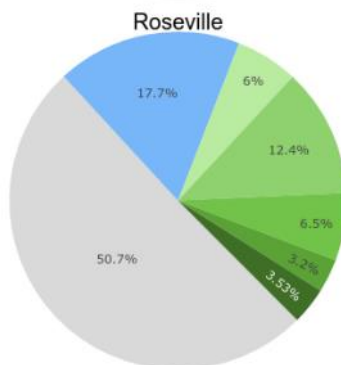
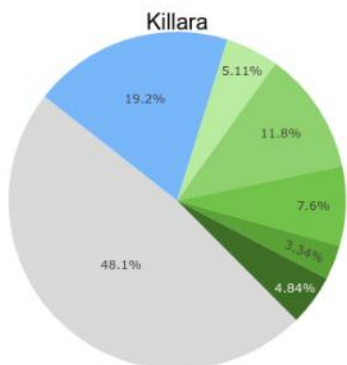
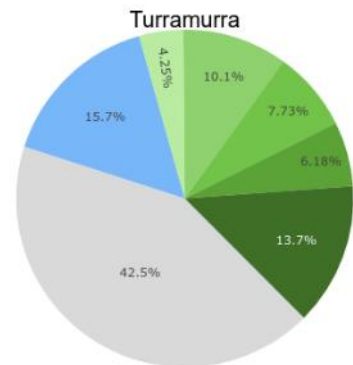
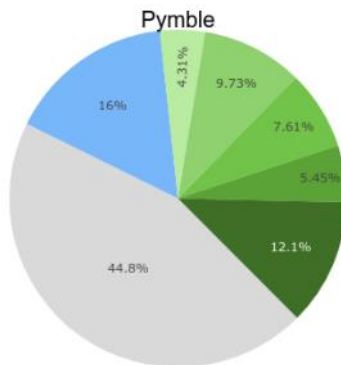
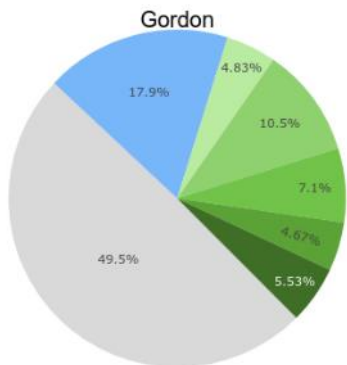


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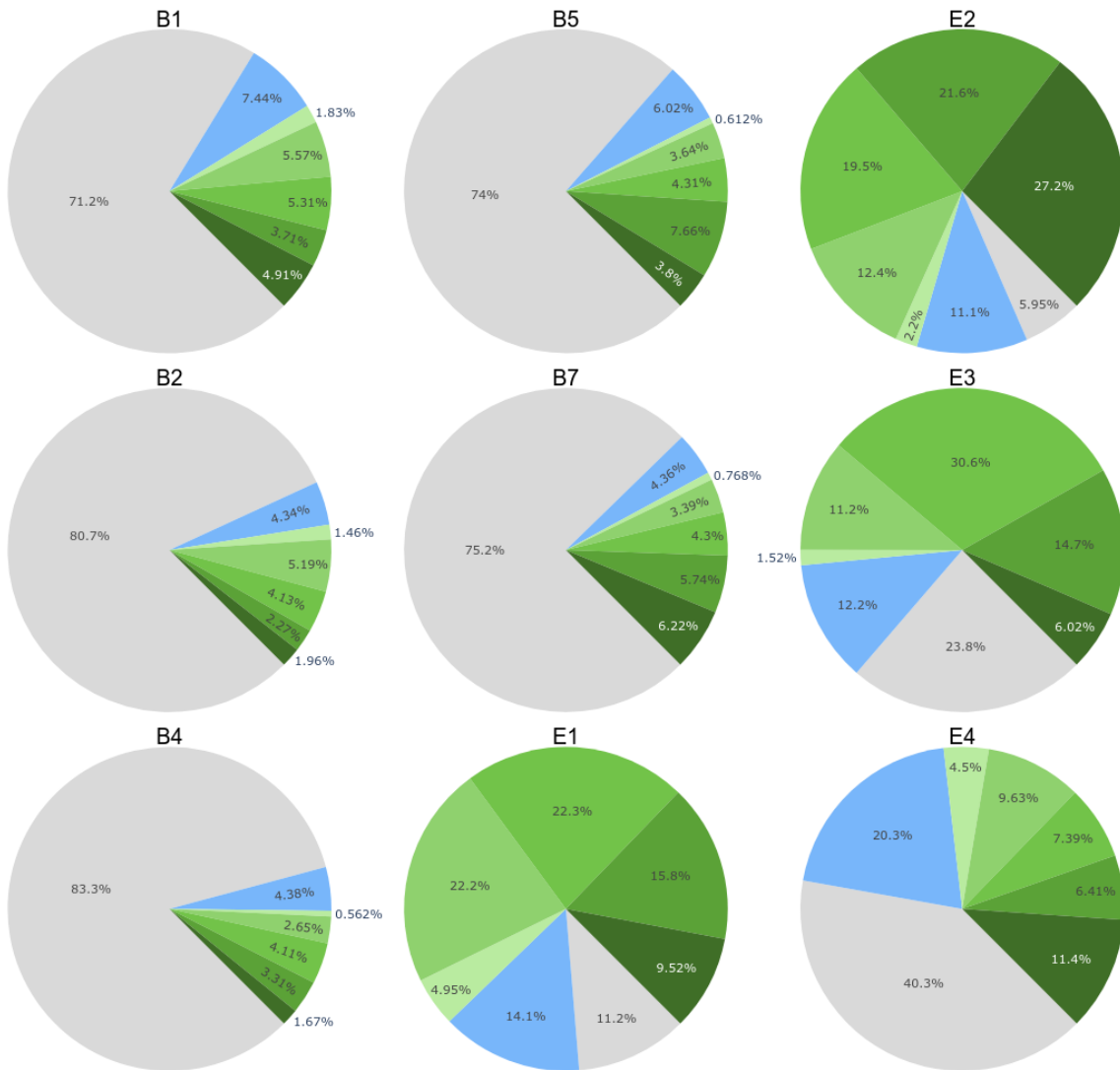
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Appendix D – Town Centres

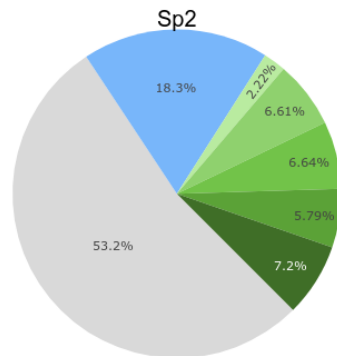
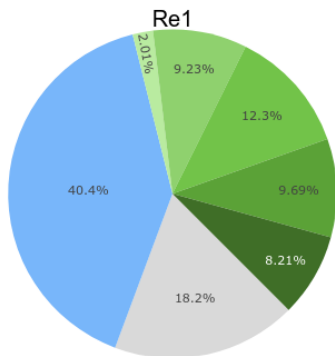
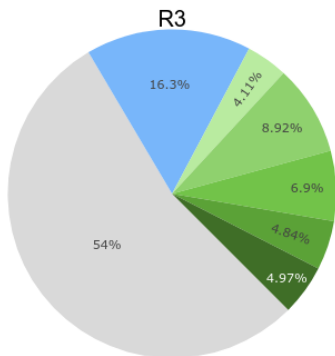
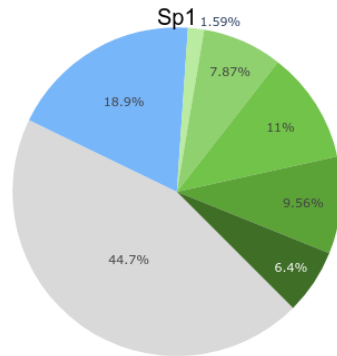
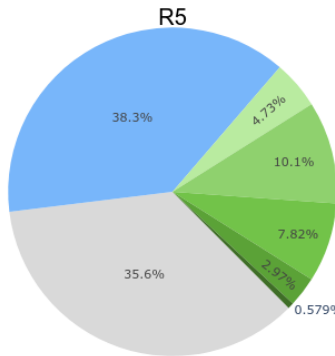
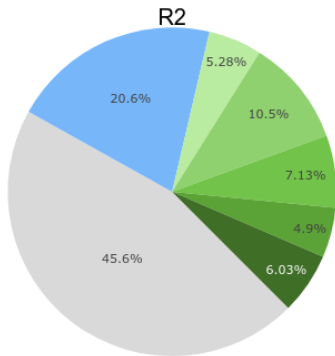
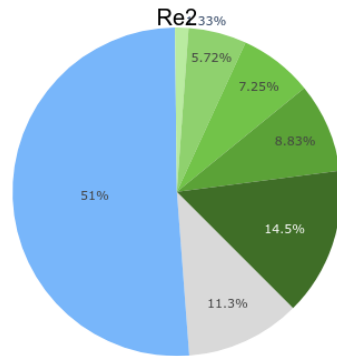
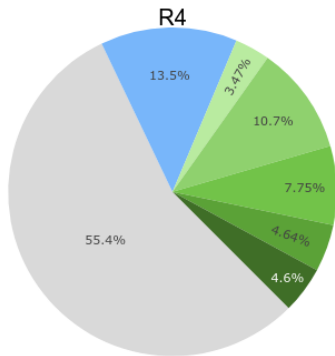
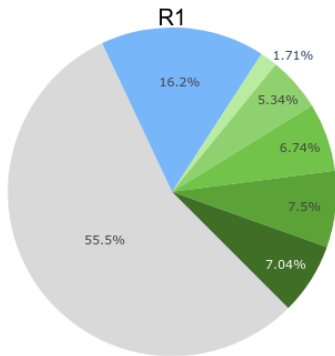


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Appendix E – Land Use Zones



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