Tree Canopy Cover Assessment

An assessment of tree canopy cover in Woodville West, St Clair and Findon between the years 1998, 2008 and 2014 using the i-Tree Canopy tool.

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Abstract: The i-Tree Canopy tool (a free on-line assessment tool) was used to determine an estimate of the percentage of land cover in Woodville West, Findon and St Clair which is tree canopy, shrub, grass/bare ground and hard surface, with distinction between public and private land. Surveys were conducted for the years 1998, 2008 and 2014. The results demonstrate that hard surfaces are generally increasing at the expense of tree canopy, shrubs and grass/bare ground. Private tree canopy is in decline whilst public tree canopy has increased in each of the studied suburbs. This study reveals the practicality of the i-Tree Canopy tool for further studies of this nature in the City of Charles Sturt and contributes to the understanding of development pressures upon living assets. This study supports the 202020 vision which includes measuring and promoting urban tree canopies, aiming to increase urban green space by 20 per cent of current levels by 2020. This study aligns with the national urban tree canopy assessment Benchmarking Australia’s Urban Tree Canopy which was published in 2014 by the Institute of Sustainable Futures, providing estimates of the current levels of urban tree canopy in metropolitan Local Government Areas across Australia.
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Introduction

The City of Charles Sturt (CCS) is one of sixty eight Local Government Areas (LGAs) within South Australia. The City supports a growing population of approximately 105,000 residents (CCS, 2013). The boundary of this LGA extends west from Adelaide’s central business district to the metropolitan coastline. The boundaries of the City are shown in Figure 1: The CCS, including suburbs chosen for the tree canopy assessment: Woodville West, St Clair and Findon. The urban renewal projects within the CCS play a significant role in fulfilling the objectives of the 30 Year Plan for Greater Adelaide, published in 2010 by the South Australian Department of Planning, Transport and Infrastructure, this plan promotes sustainable urban infill across the state’s capital.
Study Area

Figure 1: The CCS, including suburbs chosen for the tree canopy assessment: Woodville West, St Clair and Findon

Inset: The CCS within the context of South Australia
Source: CCS/Dekho 2014

Inset: The CCS in the context of South Australia
Source: http://users.sa.chariot.net.au/
The benefits of tree canopy cover

Tree canopy cover is known to provide various benefits to communities encompassing biophysical, economic and social elements. One of the significant beneficial impacts of tree canopy cover and urban forests in a community is the reduction of the urban heat island (UHI) effect. This effect is primarily caused by urban structures which hold heat, increasing the heat capacity of the cities. The UHI effect is also enhanced in the presence of impervious surfaces through the inhibition of evaporative cooling (Argüeso et al., 2013). The UHI effect causes climatic alterations at a regional scale, resulting in differences between the urban areas and surrounding rural areas. The microclimate of a city is also significantly influenced by the land cover surfaces, exacerbating the impact of the UHI effect (Kleerekoper, 2012). Wong et al. (2013) has found that a city’s UHI effect directly influences the number of extreme heat events which has negative impacts on the health of urban populations as it is more difficult to live comfortably and sustainably in extreme heat. The UHI effect is of particular concern in the context of South Australia because of the Mediterranean climate with arid surroundings to Greater Adelaide, with relatively frequent extreme heat events during the summer. Climate projections by the International Panel on Climate Change indicate that Mediterranean climates are more likely than other climate systems to experience a future drying trend (Bardsley and Sweeney, 2010). The effects of this drying will cause enhanced heat islands within the urban area, creating a higher reliance on tree canopy and urban green space to mitigate the UHI effect.
Further benefits of tree canopy cover include:

- Improvements in air quality. Nowak (2002) reports that urban trees improve air quality in the following ways:
  - Temperature reduction through increasing radiation absorption and heat storage whilst reducing wind speed, relative humidity, turbulence and albedo (the reflecting power of a surface).
  - Removal of gaseous air pollution such as fine particulate matter from vehicle exhaust emissions. The larger and healthier the tree, the greater the pollution removal.
  - Reducing the community’s energy requirements through shading buildings in the summer and blocking winds in the winter.

- Improvements in stormwater management. Trees with broad canopies intercept rainfall which reduces the amount of stormwater that reaches sewerage and river systems, delaying peak flows (Livesley, Baudinette and Glover, 2014).

- Provision of beneficial visual stimulus for urban residents. For example, a study by Herzog and Miller (1998) found that the common response to forest and field settings is attraction whereas urban alleys evoke an experience of danger.

- Maintenance of habitat for native (and other) fauna, which can include vulnerable or threatened species in fragmented urban landscapes (Jacobs, Mikhailovich and Delaney, 2014).

- Provision of spaces for interaction, amenity and recreation, which improve community health and well-being (Jacobs, Mikhailovich and Delaney, 2014).
Project aims and relevance to broader visions

A comprehensive report, “Benchmarking Australia’s Urban Tree Canopy”, published in 2014 by the Institute of Sustainable Futures and the University of Technology Sydney (UTS) provides analysis of urban tree canopy in Australia’s cities. The CCS was one of 139 LGAs which was assessed and is included in the “202020 Vision: A collaborative plan to increase the amount of green space in our urban areas by 20 per cent by 2020”. Focusing on Woodville West, Findon and St Clair, this pilot study has been uploaded on the 202020 Vision website for the purpose of information sharing and can be accessed via the following link:


The national study, which used comparable methodology to this study, found that 13.2 per cent of land cover in the CCS is tree canopy; as shown in Figure 2: Tree canopy cover in South Australia’s metropolitan LGA’s. This is well below Australia’s urban average of 39 per cent and the South Australian urban average of 21.4 per cent (Jacobs, Mikhailovich and Delaney, 2014). Aligning with the national 2020 Vision, the CCS’s Tree and Streetscape Management Plan (2010) recognises the importance of data collection of tree plantings and removals as it is “imperative that we plan for the future management of our tree population based on the actual data” (CCS, 2010: 15).
The South Australian Department of Planning, Transport and Infrastructure’s 30 Year Plan for Greater Adelaide (2010) promotes urban infill in attempt to reduce the urban sprawl of the city. The results of this study found that tree canopy cover is often compromised, particularly on private land, as a result of the planning approach encouraging urban consolidation. For example, Figure 3: An example of urban infill in Findon, shows a typical suburban block in Findon which has experienced significant land cover change due to the subdivision of blocks allowing for multiple dwellings on one piece of land. This is evident by comparing the land cover within the coloured rectangles on the image between 1998 and 2014.
Figure 3: An example of urban infill in Findon: within the three coloured rectangles dwellings have increased from five to sixteen between 1998 and 2008

Source: Aerial photographs from CCS/Dekho 2014
In order to maintain tree canopy within the CCS public tree canopy must increase to compensate for canopy loss on private land. The CCS currently operates the following initiatives to promote public tree canopy within the City:

- **Whole Street Planting Program**: Streets for this program are selected primarily based on the absence of trees, the overall condition of the existing trees in the street and whether the existing species are appropriate for the locality. In 2014 a total of 26 streets were included in the CCS’s Whole Street Planting Program. 
  
  *Figure 4: Whole street planting 2004 - 2014* shows the number of street trees planted within this program each year between 2002 and 2014.

- **Trees for the Future**: A program to provide significant trees (Red Gums and other natives) on public reserves for future generations and to green the city.

- **Planet Ark National Tree Day**: In 2014 the 27th of July was proclaimed National Tree Day, promoting Australia’s largest community tree planting and nature care event. The City of Charles Sturt supports this initiative annually.

- **Reactive street tree planting**: This initiative provides residents with the opportunity to request a tree on public land adjacent to their property. Trees are only planted on this basis if the resident/ratepayer agrees to the planting and to watering the tree for a minimum of three years.

- **Adopt-a-tree**: This program has been developed to encourage members of the community to assist in maintaining a street tree. Participants are provided with information, a bucket and gloves to help them maintain their tree, with ongoing support and advice from the City.

These programs allow the CCS to plan towards increasing tree canopy on a systematic basis. Whole Street Planting contributes most significantly to the increase in tree canopy cover on public land, whilst the other programs support residents to gain awareness and appreciation for the urban forest.
This study aims to support the achievement of the Council’s goals through quantifying a baseline measure and retrospective assessment of land cover at a suburban level whilst distinguishing between public and private land. Acting as a pilot study for potential future tree canopy assessments, the results of this study will allow for informed future planning decisions in Woodville West, Findon and St Clair. This report also reveals the practicality of the i-Tree tool for the purpose of tree canopy assessment in the City of Charles Sturt.
Study area

The three suburbs assessed in this study have been selected by CCS staff in the Open Space Policy and Planning Business Unit because these suburbs have experienced substantial developmental and/or intergenerational change over the period 1998 – 2014. The three suburb boundaries are outlined in Figure 1: The CCS, including suburbs chosen for the tree canopy assessment: Woodville West, St Clair and Findon within the context of the City of Charles Sturt and individually with historical comparisons in the following figures:

- Figure 5: Aerial Photograph of Woodville West in 1998
- Figure 6: Aerial Photograph of Woodville West in 2014
- Figure 7: Aerial Photograph of Findon in 1998
- Figure 8: Aerial Photograph of Findon in 2014
- Figure 9: Aerial Photograph of St Clair in 1998
- Figure 10: Aerial Photograph of St Clair in 2014

Woodville West

Woodville West is currently undergoing Stage 2 of the urban regeneration project: The Square at Woodville West, which began in December 2011. This is a State Government led initiative and was a ‘fast-track’ development & Apartment Construction Cost Demonstration project, the first of its kind in South Australia (The Urban Developer, 2014). Over the coming years, investment of 130 million dollars will be spent revitalising this neighbourhood. The project by Renewal SA is resulting in significant changes in the suburb’s urban form, with land cover comprising of significantly increased levels of hard surfaces. This renewal project extends to less than 15 per cent of the suburb’s area, which used to be owned by Housing SA and was predominantly large housing blocks with substantial backyards.
Figure 5: Aerial photograph of Woodville West in 1998
Source: Dekho, supplied by the City of Charles Sturt, 2014
Figure 6: Aerial photograph of Woodville West in 2014

Source: Dekho, supplied by the City of Charles Sturt, 2014
Findon

Findon has experienced significant intergenerational change over the past sixteen years. Many properties which once had large family homes and backyards have been subdivided to increase real estate value. As found in this study, the private tree canopy in Findon has decreased, which is associated with urban infill. The main development sites in Findon are on the southern side of the suburb, though urban consolidation is occurring throughout the suburb.
Figure 7: Aerial photograph of Findon in 1998
Source: Dekho, supplied by the City of Charles Sturt, 2014
Figure 8: Aerial photograph of Findon in 2014
Source: Dekho, supplied by the City of Charles Sturt, 2014
St Clair

St Clair is the newest suburb in the CCS and has undergone extensive developmental change since the site was bought by private developers in 2007. The new housing development of St Clair, with 1200 new dwellings, is located on the site which had been the Cheltenham Park Race Course since 1921. As discussed further in this report, St Clair has experienced a significant increase in the level of hard surfaces and significant decreases in the level of grass/bare ground over the study period 1998 to 2014. This development is far from finished and the suburb will experience further changes in land cover as the development project progresses.
Figure 9: Aerial photograph of St Clair in 1998
Source: Dekho, supplied by the City of Charles Sturt, 2014

Figure 10: Aerial photograph of St Clair in 2014
Source: Dekho, supplied by the City of Charles Sturt, 2014
Methodology

Preliminary research

Desktop research

During the scoping stage of this study, desktop research provided background to the fields of urban green space, the use of the i-Tree tool and importantly the context of this report and presentation within the CCS. The fundamental report which has assessed tree canopy cover at a national level is, “Benchmarking Australia’s Tree Canopy Cover” by Jacobs, Mikhailovich, and Delaney (2014). The South Australian Department of Planning, Transport and Infrastructure’s “30-Year Plan for Greater Adelaide: A Volume of the South Australian Planning Strategy” (2010) also provided context to the State’s planning objectives over the coming decades.

Key reports which are relevant to the current context of tree canopy cover in the CCS:
- CCS Tree and Streetscape Management Plan (2010)
- CCS Tree and Streetscape Policy Review (2014a)
- CCS Living Green to 2020: Draft for Consultation (2014b)

The i-Tree website was explored thoroughly in order to become familiar with the tool’s capabilities and limitations, to find inspiration from similar projects and learn how to use the tool. The website www.itreetools.com provides excellent tutorial videos and documents. The website www.202020vision.com.au also provides an online space for information sharing for projects promoting urban green space, including other i-Tree studies from around Australia.
The background to i-Tree Canopy software extracted from the i-Tree website
(http://www.itreetools.org/about.php)

*i-Tree is a state-of-the-art, peer-reviewed software suite from the USDA Forest Service that provides urban and community forestry analysis and benefits assessment tools. The i-Tree tools help communities of all sizes to strengthen their urban forest management and advocacy efforts by quantifying the environmental services that trees provide and the structure of the urban forest.*

Engaging experts

The following meetings were held with the employees of the City of Charles Sturt, to provide insight into the context of this study:

- **Monday the 12th of September 2014**
  - David Wheeler - Parks and Arboriculture Support Officer
  - Mark Hannan - Strategic Planner, Open Space Environmental Management
- **Monday the 15th of September 2014**
  - Allison Bretones - Manager Open Space, Recreation and Property
  - Janet Willoughby - Strategic Planner, Open Space Services
  - Mark Hannan - Strategic Planner, Open Space Environmental Management
- **Friday the 19th of September 2014**
  - Sam Higgins - Coordinator Open Space Planning Policy and Assets
  - Chris Taras - Technical Officer Arboriculture
  - Mark Hannan - Strategic Planner, Open Space Environmental Management
- **Regular appointments for support with GIS methodology with Ricky Herrera – Senior GIS Officer**
Site visits

Woodville West, St Clair and Findon were visited on Monday the 29th of September 2014 with Janet Willoughby (Strategic Planner, Open Space Services) to gain further context of the study area and the role of urban trees in strategic planning.

GIS Software Employed for this study

Three survey methods were trialled for this study, to find the most practical and relevant method of processing the tree canopy survey. As the study progressed, a number of limitations of the i-Tree Canopy tool were exposed, requiring different software to overcome these limitations and produce accurate survey results. These methods are discussed in detail below.

i-Tree Canopy

This free-use online tool allows for the overlay of a geographically referenced file (shape-file) of suburb boundaries on to aerial imagery (provided by Google Earth) and generates random sample points for interpretation and classification by the user. Figure 11: i-Tree Canopy survey screen shows the screen which is used to process the surveys in the i-Tree Canopy application.
The i-Tree Canopy tool randomly determines points within the given boundary for interpretation and for classification, allowing the user to determine the land cover classification for each sample point. The following eight classifications were used in this study:

- Public trees: A tree with its trunk planted on public land
- Private trees: A tree with its trunk planted on private land
- Public shrub: A shrub on public land
- Private shrub: A shrub on private land
- Public grass and/or bare ground: Grass or bare ground on public land
- Private grass and/or bare ground: Grass or bare ground on private land
Public hard surfaces: Hard surfaces on public land
- Private hard surfaces: Hard surfaces on private land

The inclusions in each classification are detailed in Table 2: List of categorised surfaces.

The number of sample points and the categories of classification are determined by the user. For this study, 500 random sample points were used for each survey. The i-Tree Canopy application calculates the results and standard error throughout the interpretation process, with the final results available as either Cover Percentages or Cover Area (km²) (see Figure 15: Example of i-Tree results report for Woodville West 2008).
One of the great capabilities of the i-Tree software is that the website allows information sharing between projects around the world for the provision of guidance and support with projects. The free tutorial videos are excellent to provide basic training with the tool, which was essential in the scoping phase. The online forums are also extremely useful to learn from the questions and achievements of other researchers in the same field.

The primary limitation of the i-Tree Canopy tool is that there is no metadata supplied for the aerial image provided in the tool. Through comparisons with other aerial imagery, it is estimated that the image provided is from 2010. Because of this uncertainty, this aerial image was not used. Instead, the 500 random sample points from i-Tree Canopy were exported into other software (Google Earth and ArcGIS) so that imagery from other sources could be interpreted.

Google Earth

Google Earth is a free-use online tool providing aerial imagery, including historical aerial photographs. Historical imagery of the study area is available back to the year 2000 (though image quality is not consistent), with the most recent aerial photograph of suitable quality being from 2010. Google Earth also allows for the randomly selected, spatially referenced points from i-Tree Canopy to be imported for the comparison of land cover between aerial photographs from different years. This process is shown in Figure 12: Example of the file from i-Tree Canopy overlaid into Google Earth, on 2008 aerial imagery of Findon.
Figure 12: Example of the file from i-Tree Canopy overlaid into Google Earth, on 2008 aerial imagery of Findon.

Source: Google Earth 2014

The i-Tree website provides details on how to export the sample points from i-Tree Canopy and import them into Google Earth. A limitation of relying on Google Earth imagery for the surveys is that the image resolution and therefore quality varies between years. The clearest imagery in Google Earth is from 2008 and 2010, with poor resolution 2014 imagery, this is demonstrated in Figure 13: Google Earth image quality.
NearMap

As a result of the inadequate resolution of aerial imagery available through the i-Tree tool and Google Earth, the GIS software NearMap was also employed for the 2014 tree canopy survey. NearMap provides frequent aerial photographs of very high quality. These photographs can be accessed back to 2009. As the CCS does not have a NearMap subscription, access to this software was provided for this study through the private consulting business IPOS Consulting Pty Ltd. The NearMap image from 13 August 2014 was imported into Google Earth and overlaid with the 500 random sample points extracted from i-Tree Canopy. A limitation of the NearMap methodology is the high financial cost of access to these images. Each time an image is loaded, significant data is used from the subscriber’s monthly allowance.
ESRI ArcGIS and Dekho

Imagery for 1998 is not available through i-Tree Canopy, Google Earth or NearMap which prompted the exploration of interpreting the Dekho 1998 aerial imagery in ArcGIS for the canopy survey, which was processed using the i-Tree Canopy application. This method was found to be the most efficient, consistent and reliable method, also allowing for comprehensive data analysis. ESRI ArcGIS and Dekho both require a financial subscription – which the CCS currently invests in.

Dekho is a specialised GIS application which is available for use by employees at the CCS. The program provides spatial information of all assets, property, roads and many other items within the City boundaries. Dekho was also used for all surveys to help determine the classification between public and private land, through the “identify” tool which reveals property ownership details. For the 1998 survey, Dekho imagery was imported into ArcMap as a base layer and overlaid with the i-Tree Canopy random sample points.

This survey method is replicable to further studies and is applicable to research of wider scope, allowing for comparison of results in the future as aerial imagery becomes available for each year. The limitations of this methodology have been exposed in this pilot project, allowing for greater efficiency in future i-Tree Canopy assessments. Appendix 2: i-Tree Canopy Tutorial Document for Staff of the City of Charles Sturt has been prepared and outlines how to perform a tree canopy survey using this method. The user does not require extensive ArcGIS skills, but some experience with the program would be highly beneficial. Table 1: Summary of survey methods provides a summary of the survey methods which were trialled in this study.
<table>
<thead>
<tr>
<th>Method</th>
<th>Imagery available</th>
<th>Comments</th>
<th>Used for this study?</th>
<th>Time for survey</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>i-TREE Canopy</td>
<td>Only one image available</td>
<td>Information is not available about the image supplied through the i-TREE Canopy tool.</td>
<td>No</td>
<td>Estimated 500 points to take 2.5 hours</td>
<td>No</td>
</tr>
<tr>
<td>Google Earth</td>
<td>2000 – 2014 with varying degrees of resolution</td>
<td>Best imagery is from 2008 – 2010. Other images not of high quality</td>
<td>Yes, for 2008 survey</td>
<td>500 points takes 3.5 hours</td>
<td>Yes – only if image required is clear enough to conduct a accurate survey</td>
</tr>
<tr>
<td>NearMap image in Google Earth</td>
<td>Clear images available from 2009 – 2014.</td>
<td>Subscription is required to access these images (council does not currently subscribe)</td>
<td>Yes, for 2014 survey</td>
<td>500 points takes 3.5 hours</td>
<td>No – high financial cost</td>
</tr>
</tbody>
</table>
| Dekho image in ArcGIS  | Clear images available with varying frequency from 1998 - 2014 | - Subscription required for both GIS programs (council currently subscribes to both)  
- Basic ArcGIS skills required with support from an ArcGIS expert extremely beneficial  
- Extensive data analysis potential in ArcGIS | Yes, for 1998 survey | 500 points takes 2.5 hours            | Yes                                  |

Table 1: Summary of survey methods
Data structuring and analysis

Aerial imagery

The aerial imagery used for this study was provided through Google Earth and NearMap. The dates of the aerial photography are 13 August 2014 (from NearMap), 10 February 2008 (from Google Earth) and an unknown date in 1998 (Dekho). These photographs were chosen because they provided the greatest resolution.

Classification of land cover types

Green space is often difficult to classify as categorisations can be overlapping and unclear (Aldous, 2013). The land cover classifications used in this study are consistent with the methodology used for the national tree canopy cover analysis by Jacobs, Mikhailovich and Delaney (2014), with the additional distinction between public and private property, as outlined in Table 2: List of categorised surfaces.

For the purpose of this study, public property is defined as land which is owned by the CCS, as labelled on the Council’s aerial imagery software Dekho, and public roads. Any other land is considered to be private property, including land owned by other government departments, such as public schools.
<table>
<thead>
<tr>
<th>Public Land: Land that is owned by the CCS or is a public road</th>
<th>Private Land: Land that is not owned by the CCS and is not a public road</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grass and Bare Ground</td>
<td>Hard Surfaces</td>
</tr>
<tr>
<td>- Public sports fields</td>
<td>- Buildings on public land</td>
</tr>
<tr>
<td>- Cleared areas to the side of roads and railway tracks</td>
<td>- Roads</td>
</tr>
<tr>
<td>- Public sites cleared for development</td>
<td>- Footpaths</td>
</tr>
<tr>
<td>- Public land on industrial estates</td>
<td>- Train lines</td>
</tr>
<tr>
<td>- Wetland water bodies</td>
<td>- Public car parks</td>
</tr>
<tr>
<td>- Water bodies on public land (excluding wetlands)</td>
<td>- Public tennis courts</td>
</tr>
<tr>
<td>- Public recreation buildings</td>
<td>- Public playground equipment</td>
</tr>
</tbody>
</table>

Table 2: List of categorised surfaces
It is necessary to make a distinction between different types of green space such as trees, shrubs and grass/bare ground as this provides opportunity to gauge the different proportions of ‘green spaces’ rather than grouping all levels of green cover as a single unit (Jacobs, Mikhailovich and Delaney, 2014). Hard surfaces are not always areas which cannot be used for green space, but where more innovative means of urban green space might be utilised, such as green walls and roof top gardens (Jacobs, Mikhailovich and Delaney, 2014). Figure 14: Green wall on private property in Bowden shows an example of a green wall in a suburb of the CCS.

Figure 14: Green wall on private property in Bowden
Source: Annie Charlton 2014
Sample size and standard error

A sample size of 500 random sample points was used for the survey of each suburb in the each of the years surveyed (1998, 2008 and 2014). This sample size was chosen because the more random points sampled, the lower the estimated standard error, producing higher precision results. With this sample size, all surveys achieved a standard error of less than 2.23. The detailed results of the individual surveys are outlined in Appendix 1: 1998, 2008 and 2014 Survey Results.

Data Analysis

The i-Tree Canopy tool produces a report outlining the results for each suburb surveyed. Figure 15: Example of i-Tree results report for Woodville West 2008 shows an example of the report produced, which provided results to be transferred into the Excel spreadsheet for analysis (Appendix 1: 1998, 2008 and 2014 Survey Results).
Appendix 1: 1998, 2008 and 2014 Survey Results provides a spreadsheet with the results of these reports for each suburb for the 1998, 2008 and 2014 surveys. Of most interest in the i-Tree generated report is the "% Cover" column which also gives the estimated standard error for the land cover classification. The results from i-Tree Canopy are presented to the user of the tool in both table and graph form.
Limitations of methodology

Classification generalisations

In order to categorise land cover into eight categories a number of generalisations about land cover were made. As a result, some features, such as swimming pools were included in hard surfaces. The justification behind this generalisation is that these surfaces are “non-plantable”. It is also necessary to acknowledge that land that has been categorised into grass/bare ground is generally considered “potentially plantable”, despite the fact that this includes sports grounds and urban wetlands so it is unrealistic that these will provide planting potential in the near future. Table 2: List of categorised surfaces displays the surfaces classified into each category.
Interpretation

The accuracy of results from an i-Tree Canopy study can be influenced by the consistency of interpretation by the user. For example, a sample point which is obscured by shadows, such as shown in the top photograph in Figure 16: Cross-checking between an aerial photograph and Google Earth’s street view, can hide features of land cover, giving the user options as to how to determine the classification. For example, in this case it could be difficult to determine whether the sample point should be classified as grass/bare ground, hard surface or shrub because of the shadow. To mitigate a high level of inconsistency it is necessary to develop a standard approach to classifying points in shadow. As consistent with the study by Jacobs, Mikhailovich and Delaney (2014) for tree-edge shadows, it was considered whether the shadow appears to be inside or outside the radius of the tree crown. For extended building shadows the surrounding context was considered (including cross-checking with other image sources). If it was still difficult to determine, the point was classified as a hard surface. Sample points which were difficult to categorise were cross-checked between the Google Earth imagery, Dekho, and/or (when possible) Google Earth’s street view capability. Figure 16: Cross-checking between an aerial photograph and Google Earth’s street view demonstrates the need for this additional step for some sample points. In order to maintain consistency, sample points which were difficult to classify were recorded and reconsidered at the end of each survey.
Figure 16: Cross-checking between an aerial photograph and Google Earth’s street view

Top Image: Google Earth Aerial Imagery
Bottom Image: Google Earth’s Street View
Source: Google Earth 2014
It can be difficult to distinguish between public and private land as Google Earth does not show property boundaries. To overcome this limitation, sample points which were not obviously private or public land were cross-checked with the Dekho imagery. The Dekho software provides information about land ownership and displays property boundaries.

The i-Tree Canopy method is limited to assessing from an aerial perspective, so does not detect the nature of the ground surface that is obscured by built shelters, as shown in Figure 17: Example of land cover obscured by a built shelter. To maintain consistency, points such as this were classified as a hard surface.

Despite the limitations of the methodology used, the approach was appropriate to be consistent with the national study by Jacobs et al. 2014 and to provide a baseline for comparison of tree canopy cover at a suburban level.
Figure 17: Example of land cover obscured by a built shelter

Source: i-Tree 2014
Findings and discussion

This study has found that the level of hard surfaces in the suburbs studied are generally increasing whilst levels of grass/bare ground and trees are decreasing. This is likely the result of urban consolidation as more dwellings are built on land which originally provided green space. The small number of shrubs in each study area has decreased, though the change in shrubs is not statistically significant in this study due to a small proportion of land cover classified as private shrub and no land cover classified as public shrub (refer to Appendix 1: 1998, 2008 and 2014 Survey Results). The results for St Clair are not generally consistent with similarities found between Woodville West and Findon due to the very significant development taking place on what was originally a large area of private open space (formerly Cheltenham Racecourse). The results of the surveys for each suburb in 1998, 2008 and 2014 are represented in Figure 18: Land cover for Woodville West, Findon and St Clair 1998, 2008 and 2014.
Figure 18: Land cover for Woodville West, Findon and St Clair 1998, 2008 and 2014
As shown in *Figure 19: Change in Tree Canopy Cover*, all three suburbs have experienced a decline in tree canopy cover through *private trees* and gained canopy cover from *public trees, though not at proportionate rates*. The nett effect over the past sixteen years has been a decrease of 5.2 per cent and 4.2 per cent in Woodville West and Findon respectively. St Clair has experienced an increase in nett tree canopy from 7.8 per cent to 11.4 over this period of time.

![Figure 19: Change in Tree Canopy Cover](image)

The fact that all suburbs have experienced an increase in *public trees* is a reassuring indication that the CCS’s public tree strategies, such as the whole street planting program, are contributing positively to the nett tree canopy cover in these suburbs. Ideally, to ensure the maintenance of the nett urban tree canopy, the increase in *public trees* would be equal or greater than the loss in *private trees*, such as in the suburb of St Clair. Despite the loss in private tree canopy in St Clair between 2008 and 2014 of 0.6 per cent of land cover, the nett tree canopy has been maintained due to an increase of public tree canopy by 0.6 per cent.
Woodville West

The survey results for Woodville West show that the land cover category which has experienced the greatest change between 1998 and 2014 is private hard surfaces which has increased from 32 per cent in 1998 to 41.6 per cent in 2014, as shown in Figure 18: Land cover for Woodville West, Findon and St Clair 1998, 2008 and 2014. As a result of significant increase in nett hard surfaces, all other land cover types, except for public trees, have decreased. As illustrated in Figure 19: Change in Tree Canopy Cover, the Woodville West nett tree canopy has decreased by 5 per cent since 1998 due to a 5.2 per cent loss of private trees and a 0.2 per cent increase in public trees.

Findon

The changes in land cover between 1998 and 2014 in Findon show similar trends to Woodville West. As shown in Figure 18: Land cover for Woodville West, Findon and St Clair 1998, 2008 and 2014, this suburb has experienced significant increase in private hard surfaces; predominantly at the expense of private trees, public grass/bare ground and private grass/bare ground.

As a result of urban consolidation, private grass/bare ground and private trees which used to be common in backyards have been compromised to allow for multi-dwelling blocks. This is demonstrated earlier in this report, in Figure 3: An example of urban infill in Findon (page 9), within the three coloured rectangles the number of dwellings has increased from a total of five to sixteen between 1998 and 2008. It is anecdotally recognized that the large numbers of subdivisions in Findon over this time period is largely influenced by intergenerational change. For example, as land is inherited to younger generations they tend to use the land to its greatest financial value, usually involving developing more than one dwelling at the expense of the original large backyards. Using Figure 3 as an example, in 1998 the blue outline included two dwellings each with large backyards hosting trees; this area is now home to seven dwellings with almost no backyards and no trees.
St Clair

Unlike the trends noted in Woodville West and Findon, the land cover surveys for St Clair between 1998 and 2014 have shown an extreme decline in private grass/bare ground from 52.8 per cent of the suburb’s land cover in 1998 to 28.2 per cent in 2014 (see Figure 18: Land cover for Woodville West, Findon and St Clair 1998, 2008 and 2014). As clearly shown from the aerial perspective in Figure 5: Aerial Photograph of Woodville West in 1998 and Figure 6: Aerial Photograph of Woodville West in 2014, St Clair’s land cover has changed dramatically between 1998 and 2014 with the urban development project taking place where the Cheltenham Racecourse used to be. The increase in public hard surfaces is predominantly due to the construction of public roads to service the new urban development. The increase in public grass/bare ground is predominantly due to the establishment of the urban wetlands, areas retained for public open space, areas prepared for residential development and roads that have not yet been bituminised. St Clair has seen the greatest percentage of land which has changed between public and private ownership. As shown in Figure 20: St Clair land ownership 1998, 2008 and 2014, 20.2 per cent of the suburb has changed from private to public land over the past sixteen years. This is because a large area of St Clair was privately owned by the South Australian Jockey Club and is now being developed as a residential area requiring some public ownership of land.
It is important to note that not all trees provide the same level of benefits to the area. Characteristics such as age, species, leaf coverage and size influence how beneficial a tree’s canopy will be to the community. It is important to measure tree canopy as a collective asset, rather than to count individual trees. For example, although St Clair has many new trees planted as part of the suburb’s redevelopment, these new trees do not provide benefits to the same extent as more mature trees, at least until they have had time to grow and have been adequately cared for as juvenile trees.

With all three suburbs experiencing a loss of tree canopy and grass/bare ground, the impact is likely to be negative on impacts such as urban heat islands, stormwater management, air quality, habitat for urban fauna, amenity to the community and on the general wellbeing of inhabitants of these suburbs as it is known that having a higher level of urban green space has a positive impacts on the community.
Conclusions

This study provides an indicative assessment of current and retrospective land cover in Woodville West, Findon and St Clair. It is necessary to acknowledge that these three suburbs are not typical for the entire CCS due to their extraordinary levels of developmental and/or intergenerational change. The results from this study indicate that the trend for increased hard surfaces within these suburbs is at a cost to green land cover types, particularly from grass/bare ground and tree canopy cover on private land.

The minimal decline in the nett tree canopy cover for each suburb between 1998 and 2014 indicates that the City’s initiatives to increase the public tree canopy have been successful to date. Improvement upon these programs could result in stable or even increasing canopy cover despite the significant urban development and consolidation.

It is vital for tree canopy in urban areas to be maintained to ensure that the services provided by trees are not diminished. Trees are an imperative living asset to any urban landscape; the canopy must be measured, monitored and maintained in order to uphold the value of urban forests. Without a healthy urban forest, communities suffer from stresses on stormwater management, air quality and habitat for urban fauna, as well as greater challenges for urban planning with the enhanced UHI effect. Individuals in communities would also experience lower levels of general wellbeing and will be denied the opportunities provided by the amenity of urban forests.

“The best time to plant a tree was 20 years ago. The second best time is now.”

– Chinese Proverb
Recommendations

With consideration to the context and results of this study, the following recommendations are made:

- Consider methods of incentivising the maintenance of private trees in the CCS.

- Continue and increase involvement in community tree programmes such as Trees for the Future and Planet Ark National Tree Day to promote community awareness of the importance of urban trees.

- Continue the whole street planting programme and increase the number of street trees planted annually.

- Increase the density of urban forest in public parks.

- Work with private developers to prioritise urban tree canopy, ensuring that new residential developments are designed in a manner which allows for street trees and public urban forests.

- Collaborate tree programmes and research with the 202020 Vision network to participate in information sharing and increase efficiency.

- Amend the KPI for New Action 2.9.1 in the Council’s environment report, “Living Green to 2020: Draft for Consultation”. The current KPI is “Net increase/decrease in number of trees on public land”, though it would be meaningful to amend this to “Net increase/decrease in tree canopy cover on public land” so that the results can be quantified and monitored using a City-wide i-Tree Canopy survey.
• Further study: perform an i-Tree Canopy survey (using the ArcGIS/Dekho method) of the entire CCS for a baseline and retrospective assessment on tree canopy in the City. Dekho aerial imagery could be interpreted in ArcGIS for the years 2000, 2006*, 2010 and 2015, using a 3000 point i-Tree survey, to show trends over a fifteen year period. Updated aerial imagery could be surveyed every five years to monitor the tree canopy increase or decline in the City.

• There is a range of further research that could enrich the tree canopy assessment with considerations to other variables. For example, it would be interesting and useful to study the correlations between change in tree canopy cover and the City’s Whole Street Planting Program, or to assess the association between demographic change, property value change, development applications and tree canopy. It would also be interesting to assess how climatic variations, such as droughts, influence the City’s tree canopy.

*Dekho 2005 imagery is not available
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### Appendix 1: 1998, 2008 and 2014 Survey Results

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<td>141</td>
<td>28.2</td>
<td>2.01</td>
<td>0.263952</td>
</tr>
<tr>
<td>Public Hard Surfaces</td>
<td>87</td>
<td>17.4</td>
<td>1.7</td>
<td>0.162864</td>
</tr>
<tr>
<td>Private Hard Surfaces</td>
<td>117</td>
<td>23.4</td>
<td>1.89</td>
<td>0.219024</td>
</tr>
<tr>
<td>Total</td>
<td>500</td>
<td>100</td>
<td></td>
<td>0.936</td>
</tr>
</tbody>
</table>
Appendix 2: i-Tree Canopy Tutorial Document for Staff of the City of Charles Sturt

Before Starting:

- This process will be most efficient on a double screen computer.
- Ensure you have internet access, Google Earth (free to download), ArcGIS, Dekho and Excel on your computer.
- Depending on your ArcGIS skills, you may require help from a GIS Officer e.g. Ricky Herrera: rherrera@charlessturt.sa.gov.au
- Have you read this report?

- Have you explored the i-Tree website and user forums for i-Tree Canopy?
- Scope of your study. Consider the following:
  - How many random sample points will this study require?
    This is dependent on the size of your study area. It is recommended to keep the standard error below 2.3. The more sample points, the lower the standard error.
  - What classifications will you use to classify land cover?
    Consider keeping these consistent with previous studies
  - Will you distinguish between private and public land?
This is recommended. Dekho provides information on land ownership which can help determine public and private land.

- Is there quality imagery available through Dekho for the years you will be studying?

This is important. Prior to 2008, Dekho imagery is not available for every year.

1.0 Set up in the i-Tree website

1.1 Go to [https://www.itreetools.org/](https://www.itreetools.org/)

1.2 Select Applications and i-Tree Canopy
1.3 Select *Load ESRI Shapefile*
1.4 Accept the i-Tree End User’s License Agreement

1.5 Select *Browse* and copy and paste this file location to *File Name*

*File name: U:\Map_Projects\Tree Canopy\*

1.6 Select the relevant file for your survey boundary which will be a shape-file (SHP file)

It is important to choose the file which has been reprojected in latitude / longitude coordinates (you may require a GIS officer to prepare the shapefile for you).

In this example, it is the file named *Suburbs_AOI_Findon.shp*. 
1.7 Press **OK** and **OK** again

Your boundary shapefile has now been loaded in to i-Tree Canopy
1.8 Select *Configure and Begin Your Survey*

1.9 Define classifications by pressing the + button to add a new cover class. You can edit existing cover classes with the *edit* button.

In this example the cover classes used were:
- Private tree
- Public tree
- Private shrub
- Public shrub
- Private grass/bare ground
- Public grass/bare ground
- Private hard surfaces
- Public hard surfaces

Once you have filled out the *Cover Class, Abbreviations* and *Description*, select *Next.*

**1.10 Select Skip and Begin Survey**

(This capability is not set up for use outside of the American context).
1.11 Create your random sample points by selecting +.

If you are using the i-Tree Canopy aerial imagery, be sure to cross check the image.
with Dekho to determine which year this image is from. In this case, the image appears to be from 2010 (not relevant to this study), so the random sample points will be exported to ArcGIS and overlaid onto Dekho aerial imagery.

**Tip:** Determining your sample size

The sample size required for your survey is dependent on the boundary area. You should always aim to have a standard error <3.

“*Remember, the more points you survey, the lower your Standard Error, and the more precise your sampling will be. More points surveyed provide for a better estimation of Land Cover across your study area*”.

For example, for a suburb the size of Findon, the survey of 500 random sample points produced results at a standard error <2.23.

Using the following method in ArcGIS, a survey of 500 points will take approximately 2.5 hours.
1.12 Create 500 random sample points for export from i-Tree Canopy

You do not need to classify each point, as you will do this in ArcGIS.

1.13 Select Save Your Data
Specify file name and select **OK**

**Tip: Saving files**

Always save your data with a name you will recognise later.

E.G. In this case ‘Findon500unclassified.dat’

It is easier for data management purposes to use **CamelCasing** rather than **under_scores** or **spaces**.

Create folder/s where you will save and manage your data

1.14 Select **Save File** and **OK**

Your new file will automatically save to your **Downloads** folder. Cut the file from this folder and paste it into the folder you have created for your data.
1.15 Select Start Over and Yes

(Only if you have saved your 500 random sample points as described in step 1.1.14)
1.16 Select Load Previous i-Tree Canopy Project for Change Survey

Browse and select the file you have just saved in step 1.1.14.

1.17 Select KMZ Out

Specify file name. E.G ‘StClair500unclassified.kmz’ and select OK and Save File
Again, you will need to cut and paste the file from *Downloads* to your chosen data file.

You have now created a KMZ file, which you will open in Google Earth in step series 2.0.

### 2.0 Open Google Earth

2.1 *Select File → Open* → Select the KMZ file that you created in step series

Google Earth will import the random sample points onto the aerial imagery as a layer.
Option: Process survey in Google Earth

You could process your i-Tree survey using Google Earth, rather than continuing this tutorial to use Dekho imagery in ArcGIS. Using the Historical Imagery Tool, you can change the Google Earth Image date. To zoom in to each individual point, expand the layer on the left hand side, and click on the random sample point ID. As shown below, refer to the Google Earth Screen to interpret the image, but process the results in i-Tree Canopy. This method is only relevant if the Google Earth Imagery is of high resolution – the Dekho images will likely be clearer and metadata on the Dekho image is available on the mine.
2.2 Save the random sample points so that the file can be exported from Google Earth and imported into ArcGIS.

2.3 Right click on your random sample point layer and select *Save Place As*

Save this file as a KMZ file in your chosen folder (do not replace your original KMZ file)
3.0 Open ArcMap

3.1 Open a blank map document

3.2 Open the search function and type “Convert to KML”
(This tool also converts KMZ files)
This is the search function on the ArcMap toolbar.

3.3 Select and open the *KML to Layer (conversion)* tool.
This screen will open

3.4 Click on the *input* and find the file that you recently created in Google Earth
3.5 Change the output location to the folder you have created to keep your files.

Be sure the **Output Data Name** is one that is consistent with your data management.

Select **OK**
Your random sample points will now appear on your blank map document.
4.0 Open ArcCatalog from your computer’s start menu

Find your Geodatabase containing your recently created file, open the layer to its full extent by pressing the + symbol.

Drag the feature class **points** from ArcCatalog to ArcMap

You now have the feature class **points** in your ArcMap blank map. You can delete the layer which presents the points as yellow pins.
You now have each random sample point symbolised as a point.

To change the symbology of the points, **double click on the layer** and to go to the **Symbology tab**. **Click on the symbol** and choose a colour and symbol to represent to each point.
For example, I have chosen a red cross.

5.0 Import Dekho imagery as a layer in ArcMap

5.1 In ArcCatalog, navigate to the Image Server on the ArcGIS Server:
You may need a GIS Officer, such as Ricky Herrera, to authenticate your access to this server.

You now have access to the Dekho images through the Aerial Photos folder on this server.

5.2 Open the folder *Aerial Imagery* in ArcCatalog and drag the relevant Dekho imagery into your ArcMap document.
Drop the aerial photography file in ArcMap as a layer, below the points layer

You will now have the i-Tree random sample points overlaid onto the relevant Dekho aerial image in ArcMap.

6.0 Process your survey using ArcMap and i-Tree Canopy

6.1 Open the attribute table for the Points layer

To open the layer’s attribute table, right click on the layer and select *Open Attribute Table.*
6.2 The attribute table will open in ArcMap.

The column of most interest is named OID* (Object Identification).

6.3 Zoom in to each random sample point

To zoom in to a point, double click on the left hand side of the OID in the attribute table
6.4 Interpret the land cover classification for this point in ArcGIS and classify the point on the other screen in i-Tree Canopy.

(Be sure to ignore the image in i-Tree Canopy as it will be from a different period in time).

Repeat this for each random sample points until your survey is complete.

Tip: Be sure to save your work in i-Tree as you go.
7.0 Save the survey results

7.1 Select *Report* in the i-Tree Canopy Window. I-Tree will produce a report with the results of your survey.
7.2 Open an Excel document and record this information so that you can save and analyse the data.

Also view the data as *area* and record these results in excel

For example:

8.0 Repeat this process for each year required for your survey