CENTRAL COAST
GREENER PLACES STRATEGY

DRAFT

2019-2030

Central Coast Council

CENTRAL COAST
GREENER PLACES STRATEGY

DRAFT

Executive summary

The draft Central Coast Greener Places Strategy (the Strategy) is the first greening strategy for the Central Coast Council since its formal declaration in 2016. The Strategy is informed by the former Council's greening strategies and the Urban Heat Island and canopy mapping technical studies that guide the vision for greening the region. The vision for greening and a liveable Central Coast is reflected within the One Central Coast -Community Strategic Plan 2018-2028 which identifies a strong desire in our community to maintain the unique environmental attributes of the Central Coast.

Whilst the Central Coast region is characterised by green ridges and surrounded by national parks, the loss of canopy cover and green corridor in urban centres and neighbourhoods need to be better managed. In response to the loss of canopy cover, the Strategy provides a framework for enhancing and managing the Central Coast's urban forest and promotes urban greening over the next 10 years.

The Central Coast contains many unique urban ecosystems and places like Pearl Beach or Budgewoi foreshore are great examples. These places include parks that are dappled with tree cover that provide shade to residents while picnicking or swimming and reinforce the value and beauty of vegetation. Such urban forests play a vital role in the health, social wellbeing and economic sustainability of a region. Trees in our parks, streets or in our backyards provide services to us every day, improving our environment and quality of life. This Strategy acknowledges that trees often require removal, however without replacement planting nearby, a loss of the urban forest canopy will occur. As such, across the Central Coast trees and shrubs need to be managed in a strategic way, ensuring that any removed trees or shrubs are adequately replaced. This Strategy proposes a framework for the replacement of removed shrubs and trees, also identifying suburbs that are very hot or that contain low levels of tree canopy cover which over time will receive increased urban greening.

The Strategy also acknowledges the need for greening and managing urban health effects through other methods such as green walls and roofs and urban food gardens, to maintain liveability in urban centres, many of which are currently undergoing renewal which is resulting in higher population density. Maintaining functional urban ecosystems is a shared responsibility across all land tenure. Hence, more rigorous requirements on new development will be implemented in order to effectively improve landscaping and associated green infrastructure. It is important that we all work together to protect and enhance urban greenspace. C To do this, it is also proposed that community engagement programs will be developed. Importantly once implemented, the Strategy will ensure that tree canopy cover and green space is maintained in a way that improves the liveability of the Central Coast region.

ACKNOWLEDGEMENT OF COUNTRY

WE ACKNOWLEDGE THE TRADITIONAL OWNERS OF THE LAND ON WHICH WE LIVE AND PAY OUR RESPECTS TO ELDERS PAST AND PRESENT

CONTENTS

2 EXECUTIVE SUMMARY

5 INTRODUCTION

7 PLANNING FRAMEWORK

18 PURPOSE

22 BACKGROUND AND CONTEXT

33 ISSUES AND CHALLENGES

34 VISION AND PRINCIPLES

36 IMPLEMENTATION FRAMEWORK

38 IMPORTANT CONSIDERATIONS

42 MONITORING AND REPORTING

44 STRATEGIES AND ACTIONS

45 POLICY AND PLANNING

46 REFERENCES

INTRODUCTION

Central Coast Council was formed in 2016, forming one of the largest regions in NSW with a total area of 168,000 ha. Both the former Wyong Shire Council and Gosford City Council had strong position on urban greening and maintaining the green character of the region. The need for a harmonized approach for greening the region to enhance local livability resulted in the development of the Central Coast Greener Places Strategy (the Strategy).

Approximately 74 per cent of the region contains native vegetation wooded which comprise of National Parks, State Forest, Aboriginal lands and Council owned and managed natural areas, including the Coastal Open Space System (COSS). Despite this high level of tree canopy cover, developed coastal areas, such as on the Woy Woy peninsula and south of The Entrance contain less than 10% tree canopy cover.

The Central Coast is currently home to 325,000 people, which is expected to increase to 415,000 by 2036, placing an urgent need to meet the demand housing and employment. This will result in increased housing density, such as the construction of medium density housing in existing suburbs, along with the development of greenfield housing sites. The projected level of urban intensification and expansion requires careful planning for the development, maintenance and expansion of urban forest cover.

This Strategy builds on from the Greening Wyong Strategy which was adopted in early 2016 and aimed at:

- guiding proactive management of public trees, such as those located in streets and parks.
- identifying priority planting areas and identifying detailed precinct based objectives.
- developing relevant procedures and technical guidelines for tree planting along roads and identifying hazardous trees.

This Strategy provides a harmonized strategic direction for the management of urban greening in the region and expands beyond public land to incorporate all land tenure. The specific objectives of the Strategy are to:

- Identify areas affected by Urban Heat Islands, opportunities for greening and to prioritise areas for future greening activities.
- Undertake an audit for opportunities for public tree planting in priority suburbs and all areas of open space to facilitate tree planting operational planning.
- Strengthen tree removal and replacement processes to avoid the net loss of tree canopy cover.
- Establish processes for the replacement of removed private trees wherever practicable.
- Develop operational plans for public tree planting across the key priority suburbs.
- Develop education programs to promote community involvement in greening initiatives.
- Where the planting of trees is not possible, encourage the use of smaller shrubs and groundcovers as they make significant contribution towards mitigating heat island effects and enhancing urban biodiversity
- Implement other provisions for urban greening such as community garden green walls and green roofs.

PLANNING FRAMEWORK

Legal and policy framework guiding documents

A range of legislative instruments, policies and strategies, referred to as guiding documents, relate directly to the Greener Places Strategy. These guiding documents can either assist or limit the ability of Council to effectively implement the Greener Places Strategy. A summary of the guiding documents is provided below.

International treaties and non-binding agreements

Agenda 21, the Rio Declaration on Environment and Development

Australia was one of 178 sovereign states that attended the 1992 United Nations Conference on Environment and Development, commonly referred to as the "Earth Summit" in Rio de Janerio, Brazil. Agenda 21 includes a framework for the conservation and management of the Earth's resources, including how governments can implement these actions locally.

UN Convention on Biological Diversity

Australia is one of 168 sovereign states that are party to the UN Convention on Biological Diversity. This Convention requires that among other things, parties adequately consider the implementation of ecological sustainable development.

National Strategies

Australia's Biodiversity Conservation Strategy 2010-2030

This Strategy aims to, among other things, restore fragmented landscapes and aquatic systems and provide ecological corridors to improve long-term ecological resilience. While this Strategy largely relates to natural areas, reducing the impact of urban development on natural areas is also important.

New South Wales *Legislation Environmental Planning and Assessment Act 1979*

The Environmental Planning and Assessment Act 1979 governs private and public development in New South Wales. Relevant to this Strategy, the Act provides that consent authorities must adequately consider impacts of proposed development on the environment, must consider planning guidelines, such as Development Control Plans and may impose Conditions of Consent that require mitigation measures to be implemented.

Biodiversity Conservation Act 2016

The Biodiversity Conservation Act 2016 aims to, among other things, protect common and threatened species and to regulate harm to these entities. The urban forest provides habitat for a range of common and threatened species, such as parrots and flying foxes which may forage on fruits and blossom provided by the urban forest. The urban forest may also provide landscape connectivity among patches of bushland for these species. It is an offence to harm Endangered Ecological Communities, protected and threatened species protected under this Act without obtaining appropriate development consent or a biodiversity conservation licence.

Local Government Act 1993

The Local Government Act 1993 requires, among other things, for Plans of Management to be prepared for all community land. The Act has objectives for the management of land classified as parkland, which encourage, provide, promote and facilitate recreational, cultural, social and educational pastimes and activities and to improve how land can meet these objectives.

Roads Act 1993

The *Roads Act 1993* primarily deals with matters regarding public roads, however provides for a range of exemptions in which trees can be removed or pruned without completing impact assessments or applying for permits if a tree is deemed to be a traffic hazard or for the purposes of completing road maintenance.

Rural Fires Act 1997

The Rural Fires Act 1997 establishes the NSW Rural Fire Service and define its functions and makes provision for the prevention, mitigation and suppression of rural fires. Specific to this Strategy, the Rural Fires Act 1997 requires adequate bushfire mitigation measures. The Act is supported by, among other things, the Planning for Bushfire Protection Code which determines the density of trees around built infrastructure. Of particular importance to this Strategy is the 10/50 Code of Practice which allows for the removal of trees within 10 metres and slashing within 50 metres of an approved dwelling without Council consent on certain bushfire prone land.

Local Land Services Act 2013

The *Local Land Services Act 201*3, among other things, regulates clearing of vegetation on rural lands. Many of the provisions contained within the *Local Land Services Act 2013* are similar to that of the recently repealed *Native Vegetation Act 2013* in that agricultural management activities such as the felling of trees for construction timber and the clearing of fencelines are classified as complying development that do not require Council consent. Importantly in areas where the Local Land Services Act 2013 apply the State Environmental Planning Policy (Vegetation in Non-Rural Areas) 2017 and Council's Tree and Vegetation DCP do not apply.

New South Wales planning policies, guidelines and plans State Environmental Planning Policy (Vegetation in Non-Rural Areas) 2017

The State Environmental Planning Policy (Vegetation in Non-Rural Areas) 2017, aims to protect the biodiversity and amenity values created by trees and other vegetation in non-rural areas. The SEPP aims to protect vegetation in non-rural areas and allows for Council's to act as the Consent Authority for determining tree removal in these areas. The SEPP also allows for removal of vegetation that Council is satisfied is dead or dying or provides a risk to life or property.

State Environmental Planning Policy (Infrastructure) 2007

The State Environmental Planning Policy (Infrastructure) 2007 provides for limited tree removal and pruning as exempt development in health precincts if the pruning or removal is approved by an AQF 5 qualified Arborist. The SEPP allows for other tree removal or pruning only if a permit or development consent is granted by a consent authority.

State Environmental Planning Policy No 65— Design Quality of Residential Flat Development

The State Environmental Planning Policy No 65— Design Quality of Residential Flat Development, aims to, among other things, enhance the natural environmental performance of residential flat buildings by co-ordinating water and soil management, solar access, micro-climate, tree canopy and habitat values.

NSW Government Apartment Design Guidelines

The NSW Government Apartment Design Guidelines, released in 2015, includes provisions for improved retention of existing trees and the establishment of quality landscaping in building setbacks. Provisions also occur for establishment of deep soil planting beds including on building roofspace.

Central Coast policies and strategies

Tree and Vegetation Management Development Control Plan (DCP)

The Central Coast Tree and Vegetation Management Development Control Plan (DCP) aims to protect trees on privately owned land in the Central Coast, allow for the removal of undesirable species and minimise unnecessary injury to or destruction of trees and vegetation. On non-rural land, the DCP requires that the removal of trees growing more than three metres from an approved structure require consent from Council.

Central Coast Regional Plan

The Central Coast Regional Plan 2036 includes actions to protect and enhance the existing amenity of the region, in particular within open space and to protect the region's scenic amenity. Specific to this Strategy are:

- **Action 8.1** Protect the Central Coast's scenic amenity by planning for development that respects the distinct qualities of different places.
- **Action 18.4** Enhance the amenity and attractiveness of existing places
- **Action 18.5** Implement strategies to invest in open space, sporting and recreational infrastructure.

One Central Coast Community Strategic Plan

The One Central Coast Community Strategic Plan (CSP) notes that residents of the Central Coast value urban trees and tree canopies. The CSP provides support for the protection of trees and vegetation, addressing climate change and ensuring ecologically sustainable development. Themes specific to the CSP are:

- **E1** Educate the community on the value and importance of natural areas and biodiversity, and encourage community involvement in caring for our natural environment.
- **F1** Protect our rich environmental heritage by conserving beaches, waterways, bushland, wildlife corridors and inland areas, and the diversity of local native species.
- **F2** Promote greening and ensuring the wellbeing of communities through the protection of local bushland, urban trees, tree canopies and expansion of the Coastal Open Space System (COSS).
- **F4** Address climate change and its impacts through collaborative strategic planning and responsible land management.
- **L3** Ensure land use planning and development is sustainable and environmentally sound and considers the importance of local habitat, green corridors, energy efficiency and stormwater management.

This Strategy aligns to these actions through specifically promoting urban greening, undertaking appropriate management of existing green space.

Draft Climate Change Policy
The Draft Climate Change Policy includes the need to plan for future impacts of future climate on biodiversity. This Strategy does this through increasing the level of tree cover, reducing Urban Heat Islands and providing informal wildlife corridors through the urban matrix.

Urban Sustainability Strategy
The Urban Sustainability Strategy (in preparation) will attempt to decrease the environmental footprint created on the Central Coast. The reduction of the effect of the Urban Heat Island Effect and increasing urban biodiversity are consistent with the Urban Sustainability Strategy.

Greenfield Housing Guidelines
The Greenfield Housing Guidelines (in preparation) will provide a framework for among other things, improved landscaping in greenfield subdivisions.

Central Coast Biodiversity Strategy
The Central Coast Biodiversity Strategy (in preparation) will aim to ensure the maintenance of biodiversity values across the Central Coast within areas of native vegetation. This Strategy supports the Biodiversity Strategy in providing a framework to enhance the provision of wildlife habitat in urban areas which may act as informal wildlife corridors.

Figure 1: Interaction among the Greener Places Strategy and other future plans, strategies and planning controls for the Central Coast.

PURPOSE

What is an urban ecosystem?

In recent years, it has been increasingly recognised that cities and urban areas provide habitat for plants and animals. Humans are also part of this system, commonly referred to as urban ecosystems (Alberti et al. 2008).

As shown in Figure 2, the elements of the urban ecosystems are diverse, consisting of plants, animals and humans.

An urban ecosystem can occur at a variety of scales, from that of an entire region, such as the Central Coast, to an individual suburb. At a local scale, urban ecosystems may occur as an individual shrub or tree, a group of shrubs or trees or a whole park of trees, shrubs and garden beds. The urban ecosystem also provides ecosystem services to humans such as sequestration of carbon and other pollutants, provision of shade and increased amenity which are summarised below.

What is the difference between Urban Forestry and the Urban Forest?

Urban Forestry is the establishment, care, maintenance, and renewal of trees and tree populations in an urban context, collectively considered the urban forest (Miller et al. 2015).

The main focus of urban forestry is ensuring suitable species are chosen and appropriately maintained in order to maximise their longevity and benefits to users of adjacent areas (Miller et al. 2015). The urban forest may consist of trees that are remnants of native vegetation which formerly occurred or native and exotic trees planted in a landscaping context. Due to the diverse range of trees and large shrubs within an urban forest, it may contain exceptional diversity, representing several hundred species, across a range of size classes and heights (Figueroa et al. 2018). Trees that form part of the urban forest will often require removal due to disease and decay (Brack 2016). However, it's important they are replaced (Brack 2016). Nevertheless, the urban forest is not a self-sustaining entity and as such, trees which are removed or die need to be replaced with careful consideration to the future maintenance requirements (Miller et al. 2015). Importantly in increasingly urbanising areas, planning for the urban forest of the future also needs to secure space for future planting which may be on either public or private lands.

Urban Ecosystems

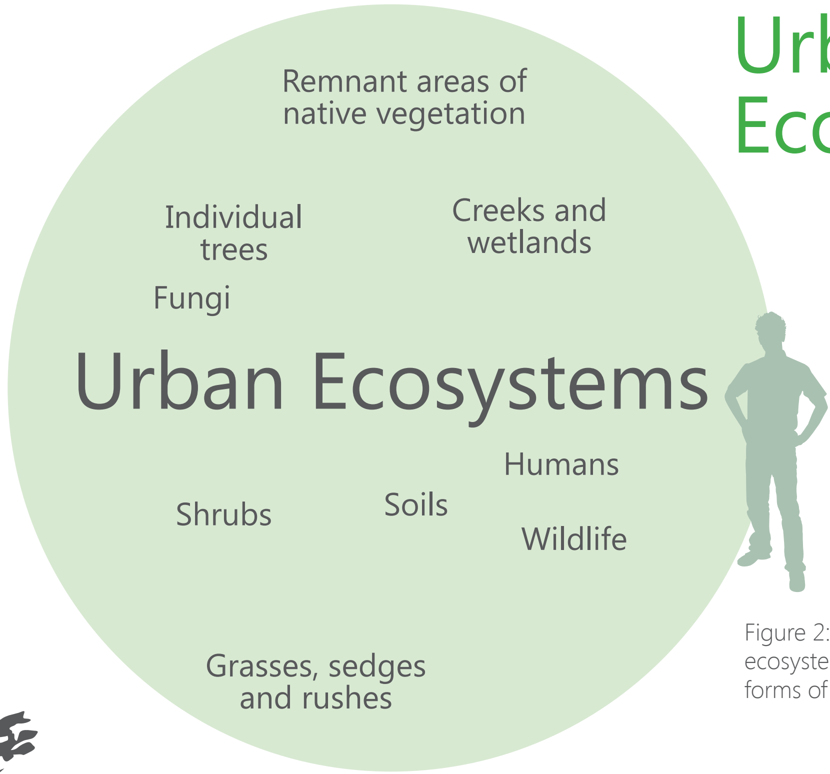


Figure 2: The elements of urban ecosystems are diverse, including all forms of life, including humans.

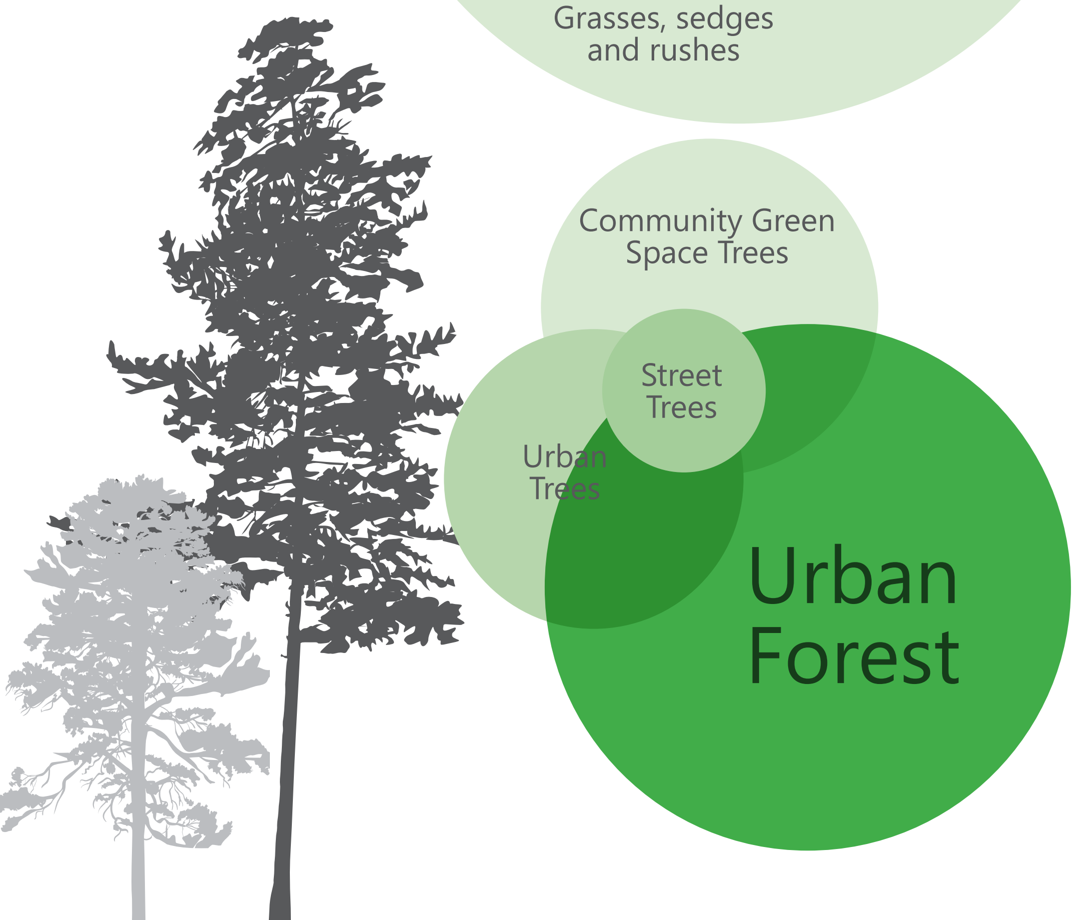


Figure 3: How the urban forest interacts with individual trees and what elements form part of the Urban Forest and how those interact together. Adapted from Roy et al. (2012).

What are the benefits of urban ecosystems?

While some negative effects may occur from vegetation in urban areas, primarily after storms, the benefits of urban vegetation far outweigh the negatives. Some of the benefits provided include:

Cooling effects

Urban trees provide shade to buildings, roads, along with private and public open space. This assists in reducing the impact of the Urban Heat Island Effect, especially during heatwaves (Amati et al. 2013, Elmes et al. 2017). Throughout the warmer months, having tree canopy shading the walls or rooves of buildings has been shown to reduce the cost of cooling. For example a study along a 19 km section of the Pacific Highway in Northern Sydney estimated energy savings from shade trees at over $57,000 per year (Amati et al. 2003).

Carbon sequestration

The urban forest completes carbon sequestration through storage of carbon in tree stems, branches and the soil (Nowak et al. 2013). Research on urban forests in the United States have calculated whole tree carbon storage measures of around 7.7 kg of carbon per square metre of tree cover, with an annual sequestration rate of around 0.3 kg of carbon per square metre (Nowak et al. 2013). A study along a 11 km section of Parramatta Road, Sydney estimated that urban trees stored 22,600 tonnes of carbon and sequestered a further 573 tonnes of carbon per year (Amati et al. 2003). Thus the urban forest provides for a high level of carbon storage and is useful in combating climate change.

Absorption and storage of atmospheric pollutants

The absorption and storage of atmospheric pollutants in leaves and the stem and branches, such as Volatile Organic Compounds (VOCs) and benzene originating from car exhausts (Nowak et al. 2002). A study on the Greater London Metropolitan area found that the urban canopy removed between 0.7-1.4% of very small particulate matter, referred to as PM10 emissions, which can trigger health issues such as Asthma (Tallis et al. 2011). A study of urban trees in a congested area of Naples, Italy found elevated levels of heavy metals in the leaves of sampled Oak trees, suggesting that the urban forest potentially stores heavy metals (Alfani et al. 1996). In an experiment conducted by researchers from the University of Technology Sydney on the effectiveness of a green wall at removing volatile organic compounds (VOCs) such as benzene and formaldehyde found that such a wall could effectively remove over half of the VOCs (Torpy et al. 2018). As such the maintenance of vegetation within areas of high air pollution may reduce the concentration of air pollutants in urban areas.

Crime prevention through environmental design aided by appropriate plantings

Areas with a high level of vegetation cover have been shown to have lower crime rates than areas with lower levels of vegetation cover (Troy et al. 2012). In a study of a highly urban area of Chicago in the United States, Kuo and Sullivan (2001) found that apartment buildings surrounded by trees had a lower reporting rate of crime than those that occurred in less vegetated areas. These findings are strongly linked to the principle of Crime Prevention through Environmental Design (CPTED) which argues that criminals make rational choices about crime targets, relating to the risk of being detected and the likely gain (Crowe 2000). Areas that have improved physical appearance are thought to be less likely to attract criminal elements as there is a strong perception that crime is correlated to areas that are less cared for (Crowe 2000).

Improved scenic amenity, health and wellbeing, enhancement of real estate values and consumer spending

The urban forest can improve scenic amenity through softening vistas, which otherwise may be dominated by the built form (Orland et al. 1992). This in turn can improve real estate prices, with leafy suburbs generally selling for more than less leafy suburbs (Orland et al. 1992). A study of retail shoppers in the United States showed that having large trees adjacent to the shopping district consumers were more willing to pay for parking, visit the shopping district more often and for a longer period of time compared to areas that were devoid of trees (Wolf 2005). A study in the state of Georgia in the United States found that properties that contained mature trees sold for around 3.5-4.5% more than properties that were devoid of trees (Anderson and Cordell 1988). A study in Finland found that dwellings that had a leafy outlook were on average 4.9% more expensive than similar dwellings that did not have a leafy outlook (Tyrväinen and Miettinen 2000). In a study in Southern England, it was found that increased time spent in leafy areas decreased depression and increased social cohesion (Cox et al. 2017).

Provision of habitat for urban wildlife, including informal wildlife corridors

The urban forest provides habitat for a range of urban wildlife. Gardens in suburbia having been shown to provide habitat for a range of small native birds (Parsons et al. 2006) and some native mammals (Carthew et al. 2014). The urban forest provides habitat resources for wildlife such as flowering blossom, fruits and denning opportunities within tree hollows. The urban forest may also function as an informal wildlife corridor, providing stepping stones among patches of remnant native vegetation through which wildlife can move through.

Approximately 74% of the Central Coast consists of native vegetation, of which around half occurs in conservation areas managed as Council reserves, State Forests and National Parks. These areas are important habitat for a range of threatened species such as the Yellow-bellied Glider and Powerful Owl. However outside of these areas, urban trees may provide habitat for other threatened species, such as the Eastern Osprey which may roost or nest in very tall Norfolk Island pines in the Blackwall area or the Grey-headed Flying Fox, Swift Parrot and Little Lorikeet which may occasionally forage on flowering Eucalypts such as Swamp Mahoganies in parks. For protected wildlife, a wide range of birds may also utilise the urban forest for foraging, such as the Brown Cuckoo Dove, Laughing Kookaburra and Rainbow Lorikeet. Urban forests may act as a stepping stone between patches of bushland, allowing wildlife to disperse or migrate across the region.

Other benefits of Urban ecosystems

Over the past decade there has been a greater recognition of the contribution that structures such as constructed wetlands, raingardens and vegetated infiltration trenches towards enhancing the urban ecosystem. A study of the use of constructed wetlands by waterbirds in Melbourne found that they provided habitat for 35 species of waterbird and 91 types of phytoplankton (Murray et al. 2013).

While smaller structures such as raingardens and vegetated infiltration trenches may not provide this scale of benefits to the urban ecosystem, they still provide habitat for pollinators and reduce impacts of stormwater runoff on nearby wetlands, creeks and estuaries (Asleson et al. 2009).

Case study: what was the value of street trees along the Pacific Highway in Sydney?

A study completed by Amati et al. (2013) along a 19km stretch of the Pacific Highway estimated 40% tree cover immediately adjacent to the road, covered by around 40,000 trees. This removed:

- 11 tonnes of pollutants per year
- Stored 71,700 tonnes of carbon across their life
- Sequestered 1220 tonnes of carbon across a year
- Produced 2110 tonnes of oxygen across a single year

This study shows the value of street trees at reducing pollution and increases the efficiency of cooling systems.

Case study: older trees have greater habitat value than younger trees in the urban forest

In the Australian environment, tree hollows are very important for wildlife, with a wide range of species such as parrots, gliders and owls all requiring hollows for breeding or denning (Gibbons and Lindenmayer 2002). However tree hollows take over 100 years to form and are found in very large trees rather than smaller trees (Gibbons and Lindenmayer 2002). Furthermore large trees generally produce more nectar than smaller trees, thus increase their value to nectar feeding wildlife such as parrots and Flying Foxes (Law and Chidel 2008). Due to these factors, old trees, in particular those that contain hollows have paramount importance in the urban forest and should be maintained and removal should only occur as a last resort. However it must also be remembered that young trees eventually become the next generation of old trees and smaller trees must also be valued and appropriately managed to ensure they are also only removed as a last resort.

Why does the Central Coast need a Greener Places Strategy?

The Central Coast is currently home to 325,000 people, which is expected to increase to 415,000 by 2036, with the growth being met by increased demand for housing and employment (NSW Department of Planning and Environment 2016).

This will result in housing intensification in existing areas, such as the construction of medium density housing in existing suburbs, along with the development of greenfield housing sites, in the area covered by the North Wyong Shire Structure Plan (NSW Department of Planning and Environment 2016). Industrial areas of the Somersby Plateau and North Wyong will also continue to be developed (NSW Department of Planning and Environment 2016). The projected level of urban intensification and expansion will require careful planning for the development, maintenance and expansion of urban forest cover. The Gosford CBD will be subject to the extensive development of residential flat blocks and other medium to high density buildings. These developments may remove urban canopy cover and increase the Urban Heat Island effect and as such, require strategic management of urban forests to reduce these effects.

The Central Coast contains a unique environment with a high level of tree cover.

This level of tree cover contributes to a number of unique suburbs, such as Pearl Beach. The Central Coast Community Strategic Plan 2018-2028 (Central Coast Council 2018) notes that residents of the Central Coast value urban trees and tree canopies. The Central Coast Regional Plan also aims to increase the amenity of existing urban areas and to protect the region's scenic amenity (NSW Department of Planning and Environment 2016). These can be achieved in part through the protection and expansion of the urban forest.

Urban Heat Island mapping has shown that on hot days, the Central Coast's 10 hottest suburbs are between 3.4 and 5.7°C above background levels (see Appendix). For example the forest within Blackwall Mountain is more than 4°C cooler than nearby urban housing in Ettalong Beach (see Appendix). Between 2013 and 2018, ten suburbs became more than 1.5°C hotter compared to background levels that occurred in bushland, including an increase of 2.6°C at Ettalong Beach, 1.9°C at Blue Haven and Woongarrah, 1.8°C at East Gosford and Booker Bay and 1.72°C at Point Frederick (see Appendix). Over time unabated, the effects of the Urban Heat Island will continue and possibly intensify as a result of continued development intensification of the urban centres.

Suburb scale tree canopy coverage ranges from 7% in Booker Bay to 90% in Ourimbah, which includes areas of each suburb that are bushland (see Appendix). Across the 94 suburbs examined, there was an overall canopy level of 42% (see Appendix). While bushland is not considered as part of the urban forest for this Strategy, it offers a number of benefits in terms of reducing the Urban Heat Island Effect and as an area for conserving wildlife, thus was included in these calculations.

The urban forest often provides habitat for urban wildlife, which are valued by Central Coast residents. The expansion of the urban forest allows for greater use of flowering and fruiting trees and shrubs by wildlife. Urban wildlife is an important part of the environment and urban trees can assist in the migration of certain species, such as parrots and small honeyeaters. Other urban greening, such as gardens that contain low growing shrubs, grasses and groundcovers also increase biodiversity through providing habitat for insects and birds.

How will this Strategy enhance Urban Ecosystems?

This Strategy predominantly focuses on the maintenance and re-establishment of urban canopy, however on certain occasions the maintenance and re-establishment of urban canopy may not be possible, for example on road verges constrained by overhead cables or within small courtyards.

Furthermore rooftop gardens and green walls on residential flat blocks may also be possible where the required area of planting beds that allow for the establishment of trees is not possible. The reintroduction of low growing vegetation such as sedges, native grasses and small shrubs in these areas may mitigate the effect of the Urban Heat Island Effect and thus the investigation, planning and establishment of urban greening is included in this Strategy.

This Strategy does not include natural areas such as bushland which in the future will be considered by Council's Biodiversity Strategy and existing site-based Plans of Management for bushland reserves.

However, at times, tree planting may occur within areas of exotic grasses adjacent to natural areas or within natural assets which over time may develop into bushland. This Strategy does include a commitment to develop Citizen Science programs around urban greening. These programs also align to the actions of the draft Biodiversity Strategy and as such, these strategies will develop shared programs predominantly in the area of environmental education. Due to the diverse range of trees and large shrubs within an urban forest, it may contain exceptional diversity, representing several hundred species, across a range of size classes and heights (Figueroa et al. 2018). Trees that form part of the urban forest will often require removal due to disease and decay (Brack 2016). However, it's important they are replaced (Brack 2016). Nevertheless, the urban forest is not a self-sustaining entity and as such, trees which are removed or die need to be replaced with careful consideration to the maintenance requirements vs or enhancement tree cover for the future (Miller et al. 2015). Importantly in increasingly urbanising areas, planning for the urban forest of the future also needs to secure space for future planting which may be on either public or private lands.

The importance of maintaining sufficient urban space for the Urban Forest

Trees planted in urban sites are usually growing under conditions that are sub-optimal for maximum canopy and root system development (Moore 2001). If trees are planted in areas with insufficient space, they are not likely to fully develop and reach their full potential (Moore 2001). If trees are planted in areas with insufficient space, this may increase the likelihood of interaction between the tree and infrastructure (Ely 2010).

Regardless of the type of tree that occupies the space today, it is the space that is the most valuable commodity for the maintenance and enhancement of the urban ecosystem and urban forest. The conversion of space that may potentially host a tree, shrub or other type of vegetation to a land cover type such as concrete or a building that does not allow for vegetation to be established results in a loss of the potential of that space to contribute to urban vegetation cover.

The adage of planting the '*right tree in the right place*' is often stated although is not always applied in planting practice. Relatively few streets were originally designed to accommodate street trees, and subsequent planting periods have sought to fit popular and often quite large growing species into constrained spaces (Ely 2010). This has often resulted in significant conflict between trees, private property and infrastructure, reducing their useful life of both and increasing the likelihood of tree failures in storm events.

Ensuring the right tree is planted in the right place means that the chosen tree species must be suitable for the space when fully grown. This requires a detailed analysis of site constraints, above and below ground spatial elements, risks and opportunities prior to selecting a species. In some instances increased space may need to be created to accommodate tree planting. Importantly however, where only small spaces are available, this does not mean that no planting should occur, instead the species with the greatest potential maximum height for the space should be selected which at times may be represent small shrubs or other groundcovers.

BACKGROUND AND CONTEXT

Urban forests from Australia and the world

Melbourne's Urban Forest

The City of Melbourne's Urban Forest consists of open space areas such as the Royal Botanic Gardens and Fitzroy Gardens along with over 70,000 other public trees within road reserves and other Council managed spaces (City of Melbourne 2012). These areas are supported by the 2012-2032 City of Melbourne Urban Forest Strategy which aims to increase tree cover in the city to 40% by 2040.

Central Park, New York; an urban forest area in a metropolis

Central Park, located in Manhattan, New York is a 341 ha urban forest. It was officially opened in 1857 with almost every one of the 25,000 trees contained within being planted. Each year Central Park attracts over 37 million visitors who visit the park for walking, relaxing and attending concerts (Central Park Conservancy 2015). Central Park directly contributes to the employment of 453 people and indirectly a further 1345 full time positions associated with ancillary activities such as restaurants and other tourism operations (Central Park Conservancy 2015). From these, the value of Central Park towards the US economy has been estimated to be worth around one billion US dollars per year (Central Park Conservancy 2015).

Gothenburg's Urban Forest

Gothenburg is Sweden's second largest city, home to around half a million inhabitants. Around 70% of the Gothenburg urban area is open space, with those areas containing around 50% tree cover. It also contains numerous areas of open space and supports a large urban forest, as well as street trees. Examples of open space that forms part of the Gothenburg urban forest includes Slottskogen which is a 137 ha urban forest which was officially opened in 1874. It contains mature plantings of European trees such as Oak and Beech along with numerous walking trails. On a summers day Slottskogen is a favourite among locals who use the park for picnics under shady trees.


MWY 2
Yarramalong 19
70

What is the Urban Heat Island Effect?

An Urban Heat Island occurs when the urban area is significantly warmer than the surrounding less developed areas, such as rural lands and forests (Oke 2011). Heat islands develop due to urban materials such as concrete, asphalt, tiled rooves and gravel absorbing rather than reflecting heat which occurs when the area is more heavily vegetated (Oke 2011).

The concept of the Urban Heat Island has been in existence for over 50 years (Bornstein 1968), however as society becomes more urbanised, greater emphasis needs to be placed upon the effect during urban planning. Figure 4 demonstrates the effect of development at Erina shows the heat island effect compared to surrounding vegetated areas, which were on average 3°C hotter. This means houses and other buildings will be hotter in areas where the Heat Island Effect is operating which will translate to higher cooling costs or alternatively less comfortable conditions indoors if cooling does not occur. Furthermore on hot days taking a walk outdoors will be much warmer than if canopy cover is present over footpaths.

Figure 4: an example of the operation of the urban heat island effect at Erina where areas of vegetation are on average 3°C cooler than adjacent developed areas. Areas in red are hotter than areas that are blue.

Seed Consulting were engaged to determine the occurrence of Urban Heat Islands across the Central Coast. Open source Landsat imagery was used to determine differentials on a hot day in January 2018 and a hot day in March 2013. These analyses found that a number of urban and agricultural areas are more than 4°C above background levels (Figure 5). When considering change in the operation of heat islands over the past five years, the analysis found that large areas of agricultural land in the west of the Central Coast had become significantly warmer, along with some isolated areas of greenfield residential subdivision across the Central Coast (Figure 6). However, minor warming differentials also occurred on the Woy Woy peninsula, Kariong, Gosford city and in the greenfield suburb of Woongarrah (Figure 5). Further information on the operation of heat islands on the Central Coast is included in Appendix.

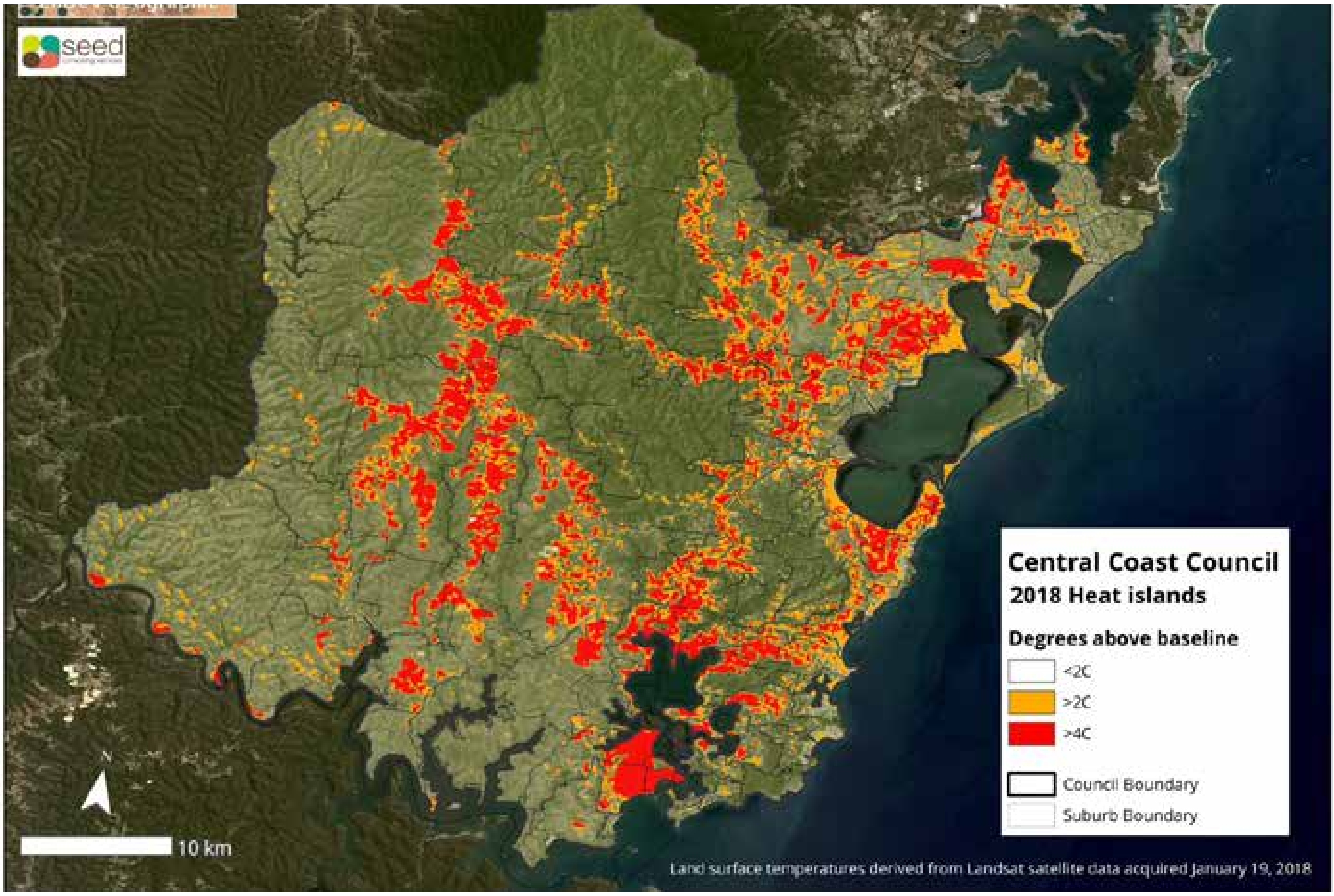


Figure 5: Areas where heat islands are more than 2ºC and 4ºC above baseline temperatures on a hot day in January 2018.

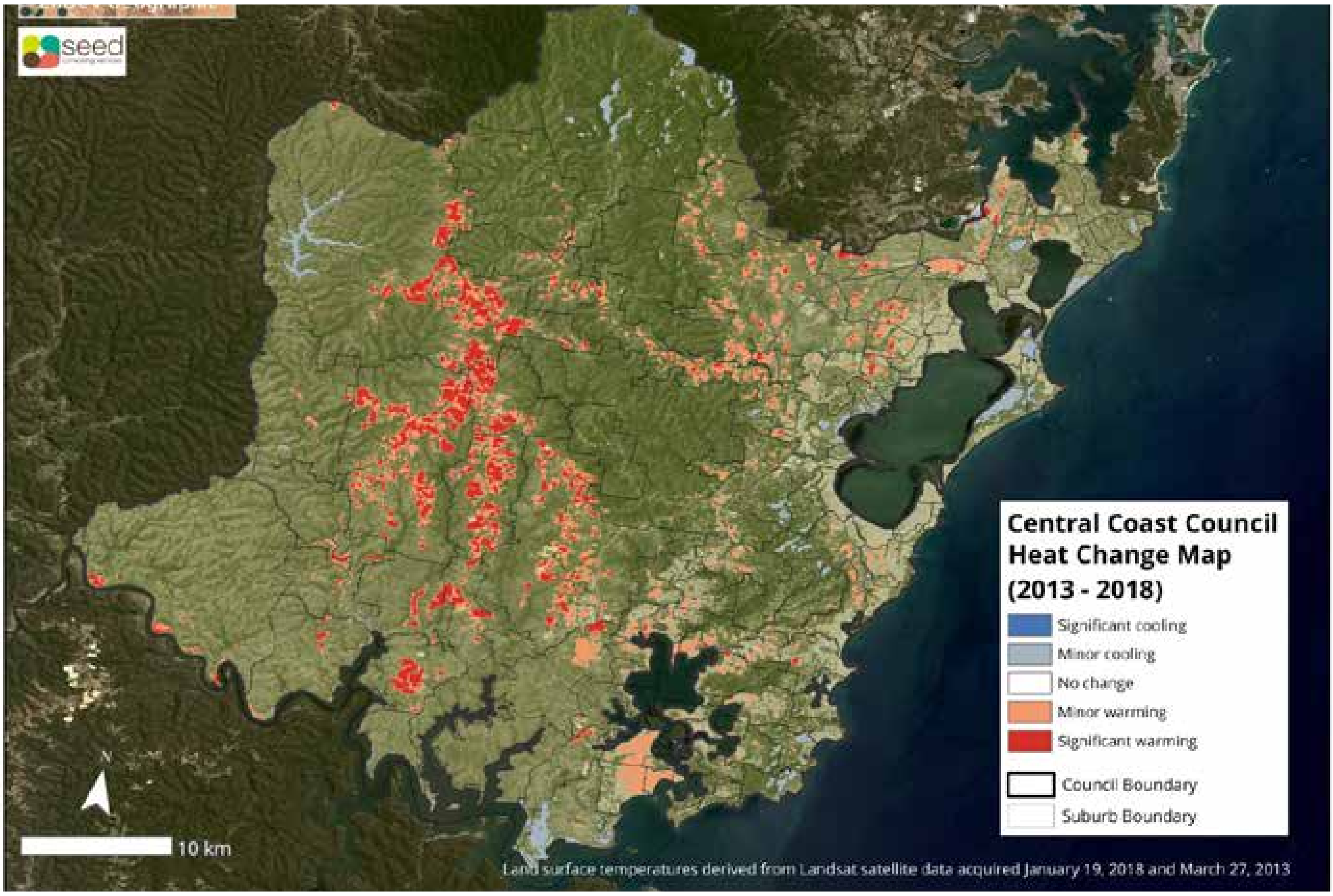


Figure 6: changes in heat islands between 2013 and 2018 for the Central Coast Local Government Area.

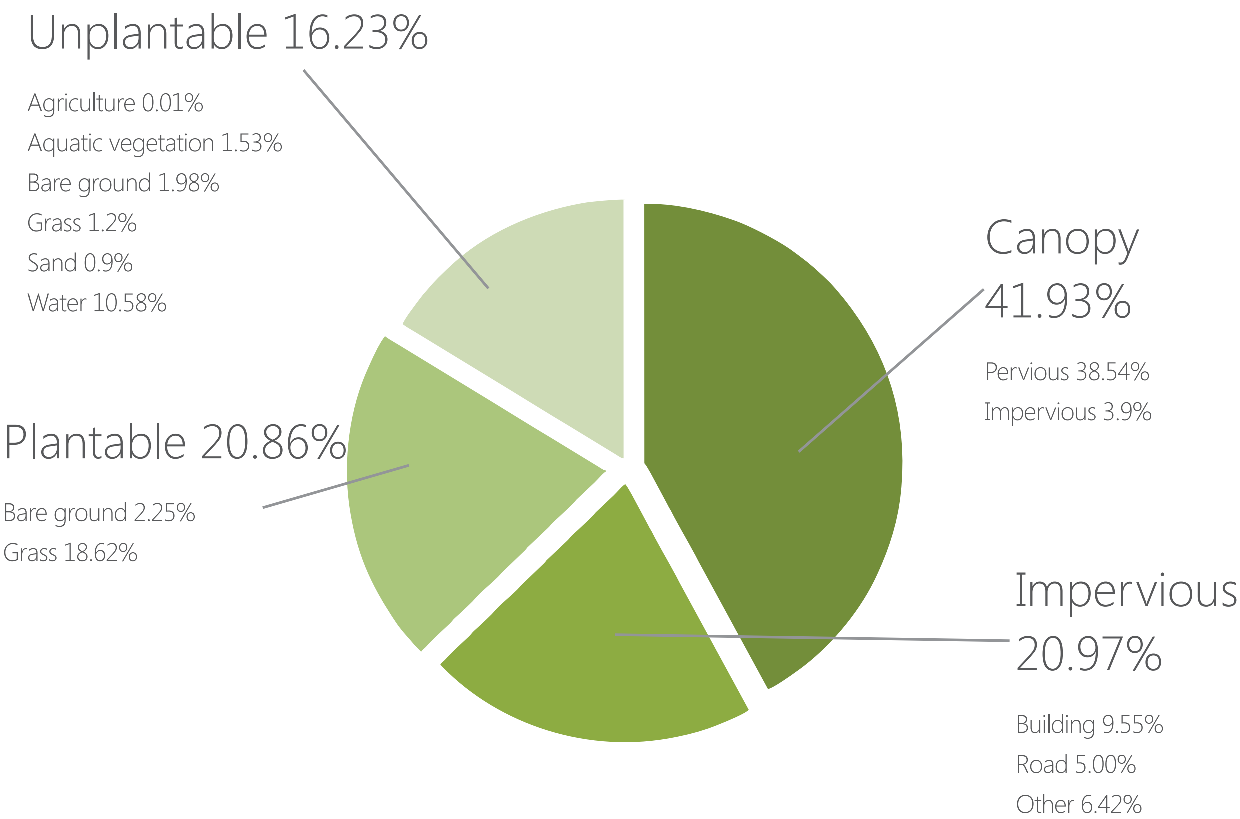


Figure 7: Overall land use breakdown for the 94 predominantly urban suburbs considered for urban canopy mapping.

Suburb scale vegetation cover

Seed Consulting were engaged to determine the level of vegetation cover for 94 suburbs that contain urban areas, with the full report being included as an Appendix to this Strategy. Seed Consulting used i-Tree, online open source software to determine the level of canopy cover in each suburb, along with the amount of impervious surfaces and opportunities for planting within grass. This process was tenure blind, meaning that the area of canopy in public compared to private ownership was not determined. One of the limitations of the process of suburb based canopy mapping is some suburbs contain large areas of National Park or State Forest which may increase the relative level of tree cover. The example of this is the suburb of Woy Woy, which includes a large area of Brisbane Water National Park, however the urban area has relatively low levels of canopy cover, giving a higher level of canopy than would occur if the National Park lands were not included in the analysis.

Within the 94 suburbs considered, an overall canopy cover of 42% was determined, with a further 21% of land containing impervious surfaces (Figure 7). This is comparable to the national urban canopy which when assessed in 2014 had an average coverage of 39%, however is lower than northern Sydney Council areas such as Hornsby and Pittwater which recorded overall average canopy coverage of 59% (2020 Vision 2014).

Overall, 21% of Central Coast suburbs contained grass or bare ground that could be planted, which may include grazing lands, while 16% of these suburbs were unsuitable for planting, including around 1% that consisted of grass with other purposes such as sporting fields (Figure 7). On the individual suburb scale, tree canopy cover ranged from around 7% at Booker Bay through to almost 90% at Ourimbah, however this included a large proportion of Ourimbah State Forest. A number of suburbs recorded levels of canopy cover of less than 15% including Blue Bay, Davistown, Ettalong Beach, Gorokan, Point Frederick, St Hubert's Island, The Entrance and The Entrance North (Seed Consulting 2018). Generally these are suburbs that are relatively established and do not contain large areas of bushland. Further information on the level of tree cover in each suburb is

Case study: changes in canopy cover at Woy Woy between 2005 and 2014

An investigation occurred as to changes in tree canopy cover and number of impervious surfaces at Woy Woy between 2005 and 2014 (see Appendix). Over this time, canopy cover declined by 173 hectares, while the area of impervious surface increased by 84 hectares and unplantable space increased by 113 hectares (Figure 8). This effect may be difficult to counteract as the area of plantable space only increased by 24 hectares (Figure 8).

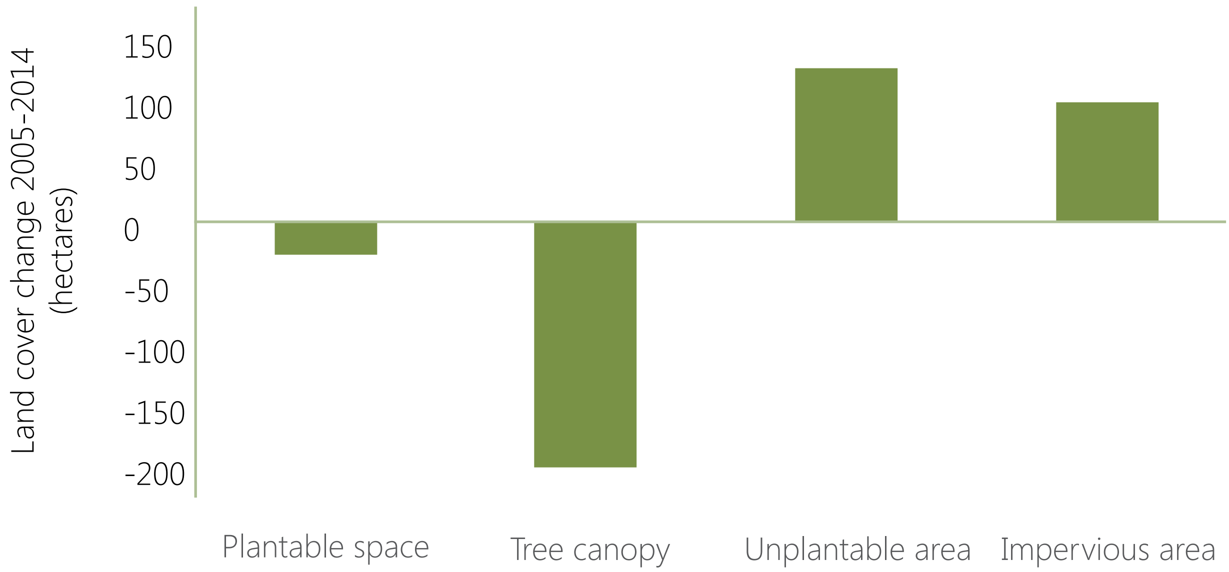


Figure 8: change in land cover categories between 2005 and 2014 for the suburb of Woy Woy.

How many public trees are there on the Central Coast?

This Strategy aims to inform broad scale strategic planning and has not attempted to estimate the number of public trees on the Central Coast.

Surveys did however occur in public recreation reserves which recorded a median tree density of 78 trees per hectare. As Council owns 663 ha of recreation reserves, it's likely that around 50,000 trees are contained within these reserves.

While an Urban Forestry Strategy or Greening Strategy may quantify the actual number of public trees within an individual local government area, such as the Melbourne City Urban Forest Strategy, these are usually determined for small local government areas and field based surveys for the Central Coast to determine the status of every tree is not practicable. Instead a reactive approach to tree risk will occur where trees reported to be a risk will be assessed on a case by case basis.

What is the optimal density for street and park trees? What type of place should we be aiming to achieve for parks and streets?

The density for street trees and park trees will vary depending on the predominant purpose of the location and the type of species chosen. In general planting densities in this strategy will be at a maximum of around 150 trees per hectare, which is the density recorded in heavily vegetated parks that still maintain grass cover underneath. However, any planting program must occur through appropriate place based planning that considers all users of the park, how tree planting will complement those uses and enhance the user experience including considering the future size of planted trees As such, parks should be assessed on a case by case basis by relevant subject matter experts before planting commences. This may instead translate to a planting density of between 50-100 trees per hectare or through trees, shrubs and groundcovers being planted in defined mulched planting areas with surrounding land being maintained as lawn.

Street tree planting is often constrained due to the presence of underground services, powerlines, footpath and kerb and gutter, which may allow for less than 0.5 metres of planting width. In these situations, smaller trees and large shrubs should be considered to ensure that damage to infrastructure does not occur in the future , as long as lines of sight are maintained (see Figure 10). Alternatively, smaller shrubs, grasses and groundcovers may be used in areas of high visual prominence where taller trees and shrubs may not be suitable and in areas where future maintenance will not be excessive.

Figure 9: photo of a park that includes a high tree density which provides shade to park users.

Figure 10: smaller street trees in Hamilton near Newcastle allow for canopy establishment in a paved footpath area while also providing shade to the footpath and parked vehicles.

Priority planting locations to increase canopy

A total of 18 suburbs have been identified for planting, based on either increasing canopy cover or mitigating urban heat island effects or to mitigate urban heat island effects in more heavily vegetated suburbs. For suburbs that have low levels of tree cover, it is anticipated that an aim of an increase of canopy cover by a further 5% will occur around 30 years after the initial installation. Where suitable public locations cannot be found for the specified number of trees, alternative mechanistic approaches such as providing trees and large shrubs to schools, health facilities, private open space providers such as golf courses and private residents where their land will strategically address the urban heat island effect and a guarantee can be provided that the tree will be maintained into the future.

Bateau Bay
Blackwall
Blue Bay
Booker Bay
Davistown
Ettalong Beach
Gorokan
Kariong
Killarney Vale
Lake Haven
Point Frederick
St Hubert's Island
The Entrance
The Entrance North
Toowoon Bay
Umina Beach
Woy Woy
West Gosford

ISSUES AND CHALLENGES

What challenges does the urban forest face?

The Central Coast Urban Forest faces a number of threats to its long-term survival, including:

- Urban infill development, which converts existing rural or larger lot residential areas to a more intensive landuse, including townhouse development. These types of developments often require extensive cut and fill excavation, which means existing remnant trees cannot be retained without compromising the tree protection zone or tree structural root zone.
- An ageing urban forest, as many of the trees of the Central Coast are remnant trees from the native vegetation that formerly occurred on the site. These trees are often mature or over-mature, thus towards the end of their Safe Useful Life Expectancy (SULE).
- The impacts from insect attack and emerging diseases. Urban trees may be stressed from insect attack, such as an overabundance of Psyllids that can cause severe dieback in Eucalypts (Hall et al. 2015). Pests and diseases can cause trees that are part of the urban forest to die or become severely stressed, which may require removal or significant pruning.
- The impacts of warming and heatwaves on tree death. Heatwaves are known to potentially result in tree death, especially if the tree is already stressed from drought (Choat et al. 2018).
- The impact on storms and floods on the urban forest. This includes trees failing due to wind throw, branch shear caused by strong winds. It is likely that storms will become more severe in the future as a result of climate change which will require consideration of which species are more resistant to storm events.
- Required clearance between trees and overhead services which require regular pruning. Pruning may reduce the structural integrity of trees and reduce their overall appearance. Ausgrid have been expanding the use of Aerial Bundled Cables for overhead services on the Central Coast which will reduce the level of required pruning in the future.
- The NSW Government's 10/50 Bushfire Code of Practice. This Code, on certain lands, permits the removal of canopy trees within 10 metres of approved dwellings, on bushfire prone land, unless their retention is required as part of a Plan of Management or development application Condition of Consent.
- Council's tree Development Control Plan (DCP) allowing the removal of any tree that occurs within 3 metres of an approved dwelling.
- The lack of appropriate replacement of trees removed for the above reasons, which may over time cause a decrease in the extent of the urban forest.

VISION AND PRINCIPLES

THE VISION

This Strategy aims to maintain and enhance tree canopy cover and green space across the Central Coast urban areas. The Strategy aims to have no loss of canopy cover across each residential suburb.

What are the overarching principles of the Strategy?

1. **The Urban Forest is a valuable community asset, providing a range of benefits.** The Urban Forest on both private and public land benefits the Central Coast community through the provision of ecosystem services, for example through limiting the effects of urban heat islands. As such, the Urban Forest is a valuable community asset.

2. **Public open space is enhanced by suitable plantings of large shrubs and trees and tree planting and replacement must be an integral part of all open space planning.** Open space planning must plan around existing plantings and supplement these as required. Trees and shrubs are an important component of open space and must be adequately included.

3. **Existing trees, in particular the space they occupy have a high replacement value and tree retention should be given precedence over removal and conversion to alternative land uses.** Once the space occupied by a tree is lost to an alternative land use such as a building or footpath, that space is unlikely to allow for replanting of trees with a large canopy. As such trees within development areas must be retained wherever possible. Trees also take several decades to become mature, with mature trees containing larger canopies than smaller ones. While trees are a resource that at times require replacement, the retention of mature trees must take precedence over removal where there is an acceptable risk to life and property.

4. **The urban forest canopy must be maintained at the suburb scale, with any loss being offset through supplementary planting nearby.** Despite the challenges to the maintenance of urban forest canopy cover in relation to increasing residential densities, Strategies must be put in place to ensure that the urban forest canopy is maintained at the suburb scale. This may include incorporation of appropriate planting areas for the establishment of medium-sized trees within higher density developments or greater emphasis on tree avoidance during the planning stage of individual developments.

5. **Trees can contribute to a particular sense of place for individual locations or suburbs and as such, tree cover in those areas should be maintained or expanded.** Trees may make a particular location feel a particular way, such as Norfolk Island pines at Terrigal and The Entrance or canopy trees retained at Pearl Beach. In areas where trees provide a particular sense of place to a location, succession planning and retention of those elements should be considered to ensure

that they are maintained into the future. If the maintenance of these specific elements cannot occur, their replacement must be supported by appropriate evidence, community consultation and support.

6. **Native trees and shrubs provide greater habitat value to wildlife than exotic species and as such, should be favoured over exotic species.** In general, native trees and shrubs provide greater habitat value to wildlife, such as rainforest trees that provide fruits and Eucalypts that provide blossom. Some exceptions do occur, such as exotic trees that produce extensive blossom or fruit; however some exotic species may become bushland weeds and should be avoided for use.

7. **The Urban Forest can provide habitat for a range of urban wildlife and may function as a corridor for birds and other wildlife.** While the bushland areas of the Central Coast act as reservoirs for biodiversity, they are often fragmented by residential or other development. The maintenance and expansion of tree canopy will allow the movement of some species of wildlife to move among bushland areas.

8. **The planting and maintenance of trees and large shrubs may not always be possible, but other urban greening can still contribute to the broad aims of urban forestry.** One of the main aims of this Strategy is to encourage the planting of trees in an urban context, however there are strong integrations with other green infrastructure, such as rain gardens, green roofs and walls and median strips planted with midstorey vegetation rather than being filled with concrete. This Strategy supports an overall increase in urban greenspace irrespective of land tenure.

9. **At times ageing or defective trees may need replacement, however their removal must be supported by appropriate expert opinion or analysis**. The Urban Forest is a living thing and as such, over time tree death, defects or disease may occur. This means that tree removal may be required, however their removal must be supported by expert opinion from an Arborist or other expert.

10. **The engagement of the community is essential in the implementation of this Strategy.** This Strategy covers all land on the Central Coast and as such, requires the engagement of the community who are able to contribute to the success of this Strategy. Community engagement may include individuals planting trees and shrubs on private land, pruning rather than removing trees on private land or participation in Council's Landcare and development of the Backyard Habitat program.

IMPLEMENTATION FRAMEWORK

Priority implementation actions

Specific targets for planting in each of the 18 priority suburbs have not been proposed as these numbers should reflect actual site conditions. It is therefore a priority to prepare suburb specific replanting plans that identify the location for each proposed tree, the most suitable size of tree and or species and from these, develop the required resourcing for implementing the suburb specific replanting plan.

At times planting may need to occur within the road reserve which may need to be reconstructed to allow for planting, such as through incursion into the pavement. In other suburbs where resources permit, available areas for replanting may also be determined and replanted where resources are available.

The field investigations completed as part of this Strategy identified an ageing canopy within Council's parks. This means that trees within the parks may require removal in the medium-term and as such successional planting needs to commence if current levels of canopy cover are to be maintained in parks. Stormwater detention basins should be assessed to determine their suitability for the establishment of canopy trees basin to determine their suitability for the establishment of canopy trees. This may be through civil works that allow for replanting of moisture tolerant trees..

This Strategy requires the consideration of green infrastructure in the form of rooftop gardens and green walls as part of all development as well as possible minor changes to Council's existing planning controls as part of the Comprehensive Local Environmental Plan project. The updated planning controls must also specify that planting is part of all development applications that come before Council for consideration. These amendments to Council's planning controls will also specify that in new developments a particular calculated area of landscaping where larger shrubs and trees can be established is required. This will increase the level of urban amenity and mitigate contributions of developments to the Urban Heat Island Effect.

This Strategy does not propose immediate planting and instead relies upon suburb scale assessments for planting opportunities in 18 priority suburbs. Along with an audit of all areas of passive open space planting plans will be developed by June 2021 with the first four suburbs being assessed by June 2020 to allow for planting to commence. The audit will consider the presence of underground and aboveground services and other constraints which will first be developed during a geographical information systems exercise which will prepare 'no go' areas before on ground assessments of possible planting locations are assessed. If a location is deemed suitable for planting, the location will be marked by a GPS and added to a database including recommended tree species.

Community education is an important part of this Strategy and as such a priority will be to develop a website informing the community on the numbers of field assessments that have been completed,

future planting locations, completed planting locations and how to become part of the Backyard Habitat program.

Council during the implementation of its work program removes trees and shrubs for the construction of roads, cycleways and other infrastructure. During these projects, this Strategy expects that the proponent of each project engage with Council's arboriculture staff to ensure the minimum number of trees and shrubs are removed for each project and the number of retained trees and shrubs are documented on Council's website. Council's Environmental Assessment method will also be modified to ensure the offset planting of removed trees at a ratio of 2:1 in a nearby suitable location.

This Strategy does not include specifications on species selection, stock selection and a procedure for determining the most appropriate species for an available location. Instead within one year of endorsement of this Strategy, Council is to prepare a species selection matrix which will be reviewed on a regular basis which will be prepared in accordance with Tree Stock for Landscape Use or any subsequent Standard.

IMPORTANT CONSIDERATIONS

Ensuring the implementation of this Strategy does not significantly increase bush fire risk

Approximately 70% of the Central Coast is classified as bush fire prone and historically large bush fires have occurred regularly. It is important that tree management completed as part of this Strategy does not significantly increase bush fire risk to assets on the Central Coast. This will be achieved by the following practices in bush fire prone land:

- Installation of large shrubs and trees rather than ground layer vegetation in bush fire prone areas, where ground layer vegetation will be maintained through regular mowing and slashing;
- Installing canopy plantings that contain smooth, less flammable bark in bush fire prone areas;
- Ensuring a gap of at least two metres occurs between the roofline any building and likely edge of canopy plantings;
- Ensuring that planted trees reach a maximum intended canopy of less than 15% foliage cover, with spacing of at least five metres between stems.
- Priority will be given to planting non-sclerophyll species at the bushland interface with species with high moisture such as Lilly Pilly and Tuckeroo.
- Suburb specific planting plan or park successional planting plan, these will be compliance with relevant Codes of Practice such as the Rural Fire Service's Planning for Bush fire Protection.

The importance of appropriate tree selection

Historically during the planting of trees on road reserves, their future size was not always considered. This resulted in damage being caused to roads and footpaths and the requirement of regular pruning of trees planted under power lines. At other times, species selection has not considered aspects such as provision of shade, benefits to wildlife or use of species that are best suited to the space.

To ensure appropriate tree species selection, the following questions must be addressed during place based planning including:

- Are there height restrictions for the site, such as overhead power lines or nearby buildings? If so, only plants with an estimated maximum height of less than five metres should be used.
- Are underground services present? If could sedges, grasses or small shrubs be used?
- Is the site highly developed such as within a main street and as such, is a deciduous species more suitable for use than an evergreen species such as allowing additional solar access in winter.
- How large is the space? Should a species that reaches a large maximum height and spread be used rather than smaller specimens from species that reach a smaller height and spread? What planting mix would best address any heat island issues?

- How can the specimen enhance the space? For example, would a large tree with a future spreading canopy enhance the space or would the space feel cramped?
- In parkland situations, which specimens will enhance the passive recreational opportunities of the area? In these situations, one or two larger species should be used instead of multiple smaller ones.
- Are there other historical plantings in the area which future plantings need to compliment? If so, the same or similar species must be considered.
- Is the site on bushfire prone land? If so, bushfire considerations need to be met.
- Is the site adjacent to bushland? If so, only local native species should be used.

The selection of appropriate tree stock is also essential, with any trees planted as part of this Strategy being in accordance wwith any relevant Australian Standard regarding Tree Stock for Landscape Use. Prior to Council accepting any stock, inspections must occur to ensure root growth and growth form is consistent with the Australian Standard.

The importance of involving community groups in implementing this Strategy

Existing community groups are already actively involved in promoting the retention and expansion of the urban forest. It is considered that these types of groups offer the greatest benefit in incorporating their on-ground work in parks rather than along roads due to the inherent risks along roadsides from utilities and traffic.

Street tree planting events will occur through Council coordination rather than through coordination by community groups. These events will occur where 10 or more properties on a street contact Council requesting street tree planting in a single application by Council staff. Council will then contact a representative of the interested residents and arrange a date for planting. Tubestock will also be provided to the residents as part of the Backyard Habitat program. It is then expected that the residents will undertake initial watering and monitoring of trees to determine if failure or damage occurs.

Development of the Backyard Habitat program

The majority of the Urban Forest occurs on private land and as such, the involvement of the community in protecting and expanding the urban forest is paramount. To maintain and expand the urban forest on private land, a three year trial of the Backyard Habitat program will be trialled where residents can join the program and receive free tubestock to be planted on their property along with advice and networking opportunities with other local residents.

What is Citizen Science and how does it relate to this Strategy?

Urban ecology is the scientific study of the relationship among plants and animals with each other and their surroundings in the context of an urban environment. In the Central Coast context, urban ecology may relate to the use of trees, shrubs and groundcovers in areas such as parks, road reserves and backyards by different species of wildlife. The urban forest is often used by a range of invertebrates, birds and mammals or may contribute foraging habitat for species such as the Gould's Wattled Bat while it forages for insects. This Strategy supports the use of Citizen Science programs to quantify the value of the Central Coast urban forest as providing habitat for fauna, including insects, mammals and birds.

Possible Citizen Science programs that will be investigated for development through the Backyard Habitat program include:

- The development of a smartphone application which allows the community to log sightings of different vertebrate and invertebrate wildlife, including the establishment on an online community that can assist with species identification.
- Annual urban ecology "BioBlitz" events to engage the community in Citizen Science activities, where the community participate in activities to survey invertebrates and vertebrate fauna in urban parks along with quantifying diversity of plants and fungi.

Processes for ensuring the replacement of removed public trees and maintenance of urban wildlife habitat

Each year Council removes over 1,500 public trees and in order to ensure that public tree canopy cover is maintained, this Strategy identifies a number of standards in which removed trees must be adequately replaced and maintained. These are:

- All removed trees must be replaced within 12 months of their removal by no less than two replacement trees.
- Where practicable, replacement trees should be planted within 50 metres of the site of the tree removal or alternatively within the same suburb.
- Replaced trees must be monitored for no less than two years and if they are substantially damaged or die during that time, they must be replaced.
- If removed public trees contain tree hollows, their loss must be compensated by the installation of at least two nesting boxes nearby for every hollow that is lost.

This process is captured within Council's internal systems and subject to regular internal reporting.

MONITORING AND REPORTING

Monitoring, evaluation, reporting and improvement strategies for the urban greening

A Monitoring, Evaluation, Reporting and Improvement (MERI) committee will be established to guide the implementation of this Strategy. It will consist of representatives from relevant sections of Council. The committee will meet twice annually and track the progress towards meeting the identified actions and benchmarks. Once every two years the committee will undertake a review of the identified actions and determine if the actions require amendment or modification, allowing for continuous improvement of the Strategy. A full review of the Strategy will occur in 2025 and 2030. The full review is to:

- Resurvey of tree canopy cover using the iTree application in each urban suburb.
- Resurvey of heat island mapping using Landsat 8 imagery to determine the level of change in heat mapping.
- Determine if the level of tree removal has changed over time and if so, if additional planting is required in suburbs not currently considered for broadscale planting.
- Determine if the levels of identified planting are being met and if not, what strategies can be put in place to meet the planting targets.

STRATEGIES AND ACTIONS

Strategic Goals

Strategic Goal 1: Sustain and enhance the existing urban forest including associated cover such as shrubs and gardens, on an intergenerational basis.

Strategic Goal 2: Ensure appropriate space is retained across all lands within the CCC LGA to allow for the direct or indirect replacement of removed trees and shrubs, and facilitate new plantings.

Strategic Goal 3: Engage and support the community during the implementation of the Greener Places Strategy

Strategic Goal 4: Ensure that a suitable tree species, in optimal densities with optimal maintenance are used for planting to ensure the urban forest reaches its full potential and reduce infrastructure interaction.

Strategic Goal 5: Establish integrated asset management between green and built assets to enable sustainable, whole of asset life outcomes for all asset classes, and reduce Council's corporate risk profile.

Strategic Goal 6: Undertake appropriate monitoring and data collection to ensure Council is informed of the status of the Urban Forest.

Strategic Goal 7: Maintain and increase habitat for urban wildlife.

Strategic Goal 8: Mitigate the Urban Heat Island Effect.

Action Categories

Policy and Planning (P&P): relates to improving policy and planning around urban greening management.

Tree Management (TM): relates to improving the management of trees on both public and private land.

Community Engagement and Education (CEE): relates to how this Strategy will engage the community.

Expanding Habitat for Urban Wildlife (EXP) which relates to how this Strategy will increase the amount of habitat available for urban wildlife, including insects, birds, reptiles and mammals.

Action number	Strategic goals	Action
Policy & Planning		
P&P 1	1,2,8	Prepare planning controls to improve tree planting and retention outcomes from development.
P&P 2	4 & 7	Develop relevant operational and technical specification manuals for urban greening & private and public tree removal / replacement in roads and open space.
P&P 3	4	Review and align relevant procedures/ processes to ensure tree management compliance with relevant Australian Standards for trees.
P&P 4	4 & 5	Develop a tree management system (tool/ database) to determine planting locations, record, analyse risk and inform ongoing tree planting (such as unmanaged land, successional planting) & replacement.
P&P 5	1, 7 & 8	Develop a Central Coast Green Grid Plan.
P&P 6	1, 7 & 8	Develop a Central Coast Green Grid Plan for the region by December 2020.
P&P 7	1	Develop methodology & process to review and update local heritage significance tree in the Comprehensive Local Environmental Plan on needs basis.
Tree Maintenance		
TM 1	1 & 2	Prepare an operational plan for strategic public tree replacement at a ratio of 2 replacement trees for every removed tree across the region.
Community Engagement & Education		
CEE1	3	Identify opportunities for community partnerships to fund and resource landscaping and streetscape improvement projects.
CEE2	3	Develop and promote community/School programs and events to improve regional biodiversity and tree management such as a Backyard Habitat program, Citizen Science program & support establishment of native gardens on private lands.
Increasing habitat urban wildlife and reducing urban heat Island effects		
EXP1	7	Review and update Water Sensitive Urban Design Manual and Civil Works Specification to increase areas of non-forested habitat.

References

2020 Vision (2014) Where are all the trees? An analysis of tree canopy cover in urban Australia, Sydney, 2020 Vision/ UTS.

Alberti, M. (2008). *Advances in urban ecology: integrating humans and ecological processes in urban ecosystems*, New York, Springer.

Alfani, A., Maisto, G., Iovieno, P., Rutigliano, F. A., & Bartoli, G. (1996). Leaf contamination by atmospheric pollutants as assessed by elemental analysis of leaf tissue, leaf surface deposit and soil. *Journal of Plant Physiology*, *148*(1-2), 243-248.

Amati, M., Brack, C., Ghosh, S., Kachenko, A., McManus, P., Shestha, K.... & Yung, S. (2013). Understanding the carbon and pollution mitigation potential of Sydney's urban forest. In *Proceedings of the Institute of Foresters of Australia National Conference, April 2013*.

Anderson, L. M., & Cordell, H. K. (1988). Influence of trees on residential property values in Athens, Georgia (USA): A survey based on actual sales prices. *Landscape and urban planning*, *15*(1-2), 153-164.

Asleson, B. C., Nestingen, R. S., Gulliver, J. S., Hozalski, R. M., & Nieber, J. L. (2009). Performance Assessment of Rain Gardens 1. *JAWRA Journal of the American Water Resources Association*, *45*(4), 1019-1031.

Bornstein, R. D. (1968). Observations of the urban heat island effect in New York City. *Journal of Applied Meteorology*, *7*(4), 575-582.

Brack, C. (2016) Our cities need more trees, but that means being prepared to cut some down, The Conversation, available online at https://theconversation.com/our-cities-need-more-trees-but-that-means-being-prepared-to-cut-some-down-53819.

Carthew, S. M., Yáñez, B. M., & Ruykys, L. (2015). Straddling the divide: den use by brushtail possums (*Trichosurus vulpecula*) in urban parklands. *Urban Ecosystems*, *18*(2), 525-538.

Central Coast Council (2018) Community Strategic Plan: One - Central Coast, Central Coast Council, Wyong and Gosford.

Choat, B., Brodribb, T. J., Brodersen, C. R., Duursma, R. A., López, R., & Medlyn, B. E. (2018). Triggers of tree mortality under drought. *Nature*, *558*(7711), 531.

Cox, D., Shanahan, D., Hudson, H., Fuller, R., Anderson, K., Hancock, S., & Gaston, K. (2017). Doses of nearby nature simultaneously associated with multiple health benefits. International journal of environmental research and public health, 14(2), 172.

Crowe, T. (2000). *Crime prevention through environmental design*. Butterworth-Heinemann.

Elmes, A., Rogan, J., Williams, C., Ratick, S., Nowak, D., & Martin, D. (2017). Effects of urban tree canopy loss on land surface temperature magnitude and timing. *ISPRS Journal of Photogrammetry and Remote Sensing*, *128*, 338-353.

Ely, M. E. (2010). *Integrating trees into the design of the city: expert opinions on developing more sustainable practices for planting street trees in Australian cities*, PhD Thesis, The University of Adelaide.

Figueroa, J. A., Castro, S. A., Reyes, M., & Teillier, S. (2018). Urban park area and age determine the richness of native and exotic plants in parks of a Latin American city: Santiago as a case study. *Urban Ecosystems*, 1-11.

Gibbons, P., & Lindenmayer, D. (2002). *Tree hollows and wildlife conservation in Australia*. CSIRO publishing.

Hall, A. A., Gherlenda, A. N., Hasegawa, S., Johnson, S. N., Cook, J. M., & Riegler, M. (2015). Anatomy of an outbreak: the biology and population dynamics of a C. ardiaspina psyllid species in an endangered woodland ecosystem. *Agricultural and Forest Entomology*, *17*(3), 292-301.

Kuo, F. E., & Sullivan, W. C. (2001). Environment and crime in the inner city: Does vegetation reduce crime? *Environment and behavior*, *33*(3), 343-367.

Law, B. S., & Chidel, M. (2008). Quantifying the canopy nectar resource and the impact of logging and climate in spotted gum *Corymbia maculata* forests. Austral Ecology, 33(8), 999-1014.

Miller, R. W., Hauer, R. J., & Werner, L. P. (2015). *Urban forestry: planning and managing urban greenspaces*. Waveland press.

Moore, G. M. (2001, September). Tree root networks: A vital ingredient of Treenet. In *Proc. 2nd National Street Tree Symp.*. Urrbrae, Australia: TREENET.

Murray, C. G., Kasel, S., Loyn, R. H., Hepworth, G., & Hamilton, A. J. (2013). Waterbird use of artificial wetlands in an Australian urban landscape. *Hydrobiologia*, *716*(1), 131-146.

NSW Planning and Environment (2016) Central Coast Regional Plan 2036, NSW Department of Planning and Environment, Sydney.

Nowak, D. J. (2002). The effects of urban trees on air quality. *USDA Forest Service*, 96-102.

Nowak, D. J., Greenfield, E. J., Hoehn, R. E., & Lapoint, E. (2013). Carbon storage and sequestration by trees in urban and community areas of the United States. *Environmental pollution*, *178*, 229-236.

Oke, T. R. (2011). "Urban heat island", in *The Handbook of Urban Ecology*, ed Douglas et al., Routledge, London, pp. 120-131.

Orland, B., Vining, J., & Ebreo, A. (1992). The effect of street trees on perceived values of residential property. *Environment and behavior*, *24*(3), 298-325.

Parsons, H., Major, R. E., & French, K. (2006). Species interactions and habitat associations of birds inhabiting urban areas of Sydney, Australia. *Austral Ecology*, *31*(2), 217-227.

Roy, S., Byrne, J., & Pickering, C. (2012). A systematic quantitative review of urban tree benefits, costs, and assessment methods across cities in different climatic zones. *Urban Forestry & Urban Greening*, *11*(4), 351-363.

Seed Consulting (2018) Central Coast Council Heat and Tree Canopy Mapping Analysis, report to Central Coast Council, Seed Consulting, Adelaide.

Tallis, M., Taylor, G., Sinnett, D., & Freer-Smith, P. (2011). Estimating the removal of atmospheric particulate pollution by the urban tree canopy of London, under current and future environments. *Landscape and Urban Planning*, *103*(2), 129-138.

Torpy, F., Clements, N., Pollinger, M., Dengel, A., Mulvihill, I., He, C., & Irga, P. (2018). Testing the single-pass VOC removal efficiency of an active green wall using methyl ethyl ketone (MEK). *Air Quality, Atmosphere & Health*, *11*(2), 163-170.

Troy, A., Grove, J. M., & O'Neil-Dunne, J. (2012). The relationship between tree canopy and crime rates across an urban–rural gradient in the greater Baltimore region. *Landscape and Urban Planning*, *106*(3), 262-270.

Tyrväinen, L., & Miettinen, A. (2000). Property prices and urban forest amenities. *Journal of environmental economics and management*, *39*(2), 205-223.

Wolf, K. L. (2005). Business district streetscapes, trees, and consumer response. *Journal of Forestry*, *103*(8), 396-400.

APPENDIX

Central Coast Council Heat and Tree Canopy Mapping Analysis

Project report

December 2018

seed consulting services

Central Coast Council
Heat and Tree Canopy Mapping Analysis

Prepared for Central Coast Council

Prepared by:
Seed Consulting Services
106 Gilles Street, Adelaide, South Australia 5000
P. +61 8 8232 4823
W. www.seedcs.com.au

In collaboration with:
EnDev Geographic

Document Control

Document information

Information	
Document Owner	Central Coast Council
Project ID	856 CCC UFS
Last Saved Date	Sunday, 18 November 2018
File Name	DRAFT Central Coast Council Heat and Canopy Mapping Report v5

Document history

Version	Issue date	Authors
Version 1	16 October 2018	Mark Siebentritt, Justin VanderBerg, Jenni Garden
Version 2	18 October 2018	Mark Siebentritt, Justin VanderBerg, Jenni Garden
Version 3	2 November 2018	Mark Siebentritt, Justin VanderBerg, Jenni Garden
Version 4	7 November 2018	Mark Siebentritt, Justin VanderBerg, Jenni Garden
Version 5	18 November 2018	Mark Siebentritt, Justin VanderBerg, Jenni Garden

seed
consulting services

Contents

1 Introduction 6
1.1 Background 6
1.2 Objectives and structure 6

2 Urban Heat 7
2.1 Assessing urban heat 7
2.1.1 Approach and method 7
2.1.2 Understanding urban heat 8
2.2 Urban heat analysis results 9
2.2.1 2018 Land surface temperature 9
2.2.2 2018 Heat islands 11
2.2.3 2013 Land surface temperature 12
2.2.4 Change in thermal landscape 2013-2018 14
2.2.5 2018 NDVI 15
2.2.6 Change in NDVI 2013-2018 17
2.2.7 Target suburbs 18
2.2.8 Limitations 24

3 Urban Canopy Cover 26
3.1 Approach and method 26
3.1.1 Focal suburbs 26
3.1.2 i-Tree Canopy 26
3.1.3 Land cover categories 29
3.1.4 Assessment errors and considerations 29
3.1.5 Case study - historical canopy change assessment 32
3.2 Urban canopy cover results 32
3.2.1 Across the urban area 32
3.2.2 Suburb specific trends 34
3.3 Case study results – land cover change in Woy Woy 38

4 Key Findings 41

References 45

Appendix A. Land Cover for Each Urban Suburb 46

Table of Figures

Figure 1. 2018 Land surface temperature map....... 10
Figure 2. 2018 heat islands map....... 11
Figure 3. 2013 Land surface temperature map....... 13
Figure 4. Heat change map 2013-2018....... 14
Figure 5. 2018 NDVI map....... 16
Figure 6. NDVI change map from 2013-2018....... 18
Figure 7. Erina suburb satellite colour image (left) and land surface temperature (right)....... 21
Figure 8. Colour imagery map of the southern target suburbs....... 20
Figure 9. 2018 Land surface temperature map of the southern target suburbs....... 20
Figure 10. Toukley colour image (left) and land surface temperature (right)....... 24
Figure 11. Warnervale colour image (left) and land surface temperature (right)....... 24
Figure 12. Colour imagery of the northern target suburbs....... 23
Figure 13. 2018 Land surface temperature map of the northern target suburbs....... 23
Figure 14. Suburbs assessed for urban canopy cover.......
Figure 15. Assessment points covered by land cover.......
Figure 16. Estimated current land cover across the urban areas of Central Coast Council. 34
Figure 17. Percent current land cover for suburbs 1-47, ordered alphabetically....... 36
Figure 18. Percent current land cover for suburbs 48-94, ordered alphabetically....... 37
Figure 19. Change in impervious, tree canopy, plantable space and unplantable space cover in Woy Woy between 2005 and 2014....... 38
Figure 20. Framework to identify priority neighbourhoods for heat mitigation activities....... 42

Table of Tables

Table 1. 2018 Ten hottest suburbs....... 10
Table 2. Suburb heat island ranking....... 12
Table 3. 2013 Ten hottest suburbs....... 13
Table 4. Suburbs experiencing the greatest warming between 2013 and 2018....... 15
Table 5. Suburb statistics of NDVI....... 17
Table 6. Suburb statistics of target suburbs....... 19
Table 7. The 94 suburbs, and their areas, assessed for this project....... 27
Table 8. Land cover categories used for i-Tree Canopy analysis....... 30

Table of Plates

Plate 1. Aerial images showing examples of each land cover category under a randomly allocated point (yellow dot)....... 31
Plate 2. Aerial images showing examples of land cover change in Woy Woy between 2005 and 2017....... 39
Plate 3. Aerial images showing example of urban in-fill in Woy Woy, and the conversion of tree canopy to unplantable bare ground to impervious....... 40

1 Introduction

1.1 Background

The liveability of cities and their resilience to climate change is influenced by a range of factors including the extent and quality of green infrastructure and the presence of urban heat islands. Tree canopy cover is a key part of green infrastructure in a city and is receiving increasing attention from urban land planners and managers nationally and internationally. This is due in large part to trees being recognised for providing multiple benefits including improved human health and wellbeing, improved amenity and air quality, and noise abatement, climate change mitigation through carbon sequestration in plants, economic benefits from enhanced commerce and property values, and climate change adaptation through reduction of the urban heat island effect by shading and transpiration.

Urban heat islands are areas that retain more heat than the surrounding landscape. The presence of urban heat islands is a key concern for local government given that extreme heat leads to greater mortality in our community than any other natural hazard. This is especially so for vulnerable members of the community. Green infrastructure, including grassed areas and trees on public and private property can help to moderate surface and air temperatures and thus reduce the impact of the urban heat island effect.

1.2 Objectives and structure

Mitigating urban heat islands and investing in green infrastructure are priorities under the Central Coast Council Community Strategic Plan. As part of its response to these priorities, Council is developing a Central Coast Urban Forestry Strategy. This Strategy will inform the management of the urban forest over the next 30 years.

Central Coast Council engaged Seed Consulting Services, working in partnership with EnDev Geographic, to undertake urban heat mapping and tree canopy analysis for the settled areas across the Council. The objectives of this project are to:

- provide exploratory insight into how landscape and development decisions have impacted heat distribution across Central Coast Council, and in turn, how heat affects liveability; and
- determine the level of tree canopy coverage across each suburb of Central Coast Council.

This work provides landscape-scale analysis of urban forest canopy cover and the thermal distribution across suburb and council scales, and over time, to provide robust decision-making support for how the Council considers its urban forest and heat effects in the planning process.

2 Urban Heat

2.1 Assessing urban heat

2.1.1 Approach and method

To provide a high-level assessment of the thermal performance of the Central Coast Council landscape, two satellite datasets were acquired from the Landsat 8 Operational Land Imager. The two datasets (captured on January 19, 2018 and March 27, 2013) were both collected on warm days with the BOM reporting a maximum temperature in the area of 30.6ºC and 29.5 ºC, respectively (BOM 2018). A timeseries of land surface temperatures and vegetation indices were created, urban heat island and change analyses were conducted, and summary statistics were calculated at the council and suburb scales.

Satellite thermal data provide an extensive, inclusive view of heat distribution across a large area, collected at a single moment in time. For this study, two Landsat 8 Satellite datasets, collected on January 19th, 2018 and March 27th, 2013 at approximately 11:05am local flyover time, were analysed to assess the thermal profile of the Central Coast Council. Landsat 8 provides the highest resolution thermal data (100m2 resampled to 30m2) freely available from satellite platforms. Each image was converted from raw digital data into land surface temperature using the standard processing protocol (Landsat 8 User's Manual 2016, Martin et. al., 2015). For each of the two Landsat datasets, land surface temperature was calculated using both bands 10 and 11 resulting in two thermal images that were then averaged to produce the composite Land Surface Temperature maps of the Council for 2018 and 2013.

In addition to general heat distribution, heat concentration was also assessed through the inclusion of a heat island assessment. Heat islands, specifically Urban Heat Islands, are any areas that exhibit a significant warming above what would naturally occur in area, driven by light coloured, low density, respirating, natural materials being replaced by high density, often dark, dry, man-made materials that absorb heat more readily, leading to artificial hot spots. To assess heat islands, the two datasets were normalized around the mean value, creating a map of "relative heat" presented in degrees Celsius above and below the mean value. Heat islands were identified as any areas warmer than 2 ºC above the mean, and extreme heat islands were identified as any areas warmer than 4 ºC above the mean.

Landsat 8 data contains nine datasets in addition to thermal information. For the same acquisition dates, the Normalized Difference Vegetation Index (NDVI) was also calculated (Al-doski et al. 2013). Plants undergoing photosynthesis give off a strong signal of near-infrared light, undetectable to the human eye. NDVI uses the difference between red and near-infrared signals to determine the amount of photosynthesis going on in a given area and is presented here as the NDVI map.

Temperatures, heat islands, and NDVI values were assessed for each of the 156 suburbs within Central Coast Council, with additional focus on the 11 target suburbs identified.

Temperature and NDVI values were calculated for both the 2018 and 2013 timepoints, and a timeseries analysis was applied to identify the trend and magnitude of changes that have occurred over the intervening period.

The key deliverables from this analysis are:

Data:

- 2018 Land Surface Temperature Dataset (.tif)
- 2018 Urban heat islands (.tif)
- 2018 NDVI (.tif)
- 2013 Land Surface Temperature Dataset (.tif)
- 2013 NDVI (.tif)
- Council results spreadsheet (.xls)
- Suburb results spreadsheet (.xls)

Maps:

- 2018 Heat Islands Map
- 2018 Land Surface Temperature Map
- 2018 NDVI Map
- 2013 Land Surface Temperature Map
- Heat Change Map 2013-2018
- 2013 NDVI Map
- NDVI Change Map 2013-2018

2.1.2 Understanding urban heat

The data collected describe the land surface temperature of the study area which directly influences air temperature. The varying influence of surface heat on air temperature is governed by local conditions known as micro-climates. In addition to surface heat, many local factors affect air temperature including building shadows, urban wind-tunnelling, and fountains which have a cooling effect, and air conditioners, traffic exhaust, and other sources of waste heat which have a warming effect. Understanding the balance between surface and air temperature requires a detailed micro-climate model.

Region wide surface temperature information provides an appropriate and sufficiently reliable indicator on which to base landscape scale recommendations about where to prioritise heat mitigation activities. This is because it reflects locations where air temperature and absorbance of solar radiation is high, which impacts directly on human thermal comfort (Matzarakis, et al., 2007 in Norton, et al., 2015).

2.2 Urban heat analysis results

Land surface temperatures and the presence of urban heat islands are discussed first based on 2018 satellite imagery followed by an assessment of the change in surface temperature between 2013 and 2018. NDVI is then assessed to provide an overall indication of greenness in 2018, and as a change since 2013, followed by discussion of the heat characteristics of 12 target suburbs nominated by Council.

2.2.1 2018 Land surface temperature

Analysis of the 2018 land surface temperature map shows a medium range of temperatures from 21 to 43 ºC (Figure 1). Warmer areas appear to concentrate among urban areas not immediately adjacent to the coast, suggesting a pronounced cooling influence from the ocean, but not from internal water bodies (Table 1). Other concentrations of heat occur in most developed areas including agricultural corridors along Peats Ridge Rd., Wisemans Ferry Rd., and George Downs Dr. Overall, forested areas presented a strong cooling signal, with some variation driven by the aspect (direction of slope) of the hills and other drivers of vegetation health.

The hottest suburbs concentrated amongst the more developed areas, near but generally not immediately adjacent to the coast. The southern end of the council holds the hottest three suburbs, all measuring greater than 4 ºC above average: Ettalong Beach, Umina Beach, and Booker Bay (*part of Woy Woy likely fits in this group as well*. For further discussion see *limitations*) (Table 1). The other hottest suburbs are spread across the central and northern regions, among near-coastal areas.

Open areas can have wide ranging heat signatures based on vegetation cover and condition. Dry barren earth can easily become some of the hottest areas in a landscape, but well-watered vegetation can be some of the coolest. Different parts of the agricultural season can have similarly divergent heat effects. As harvest season approaches, many crops are left to dry in the field, causing them to act more like barren earth than vegetation which may help explain the strong heat signal from the interior.

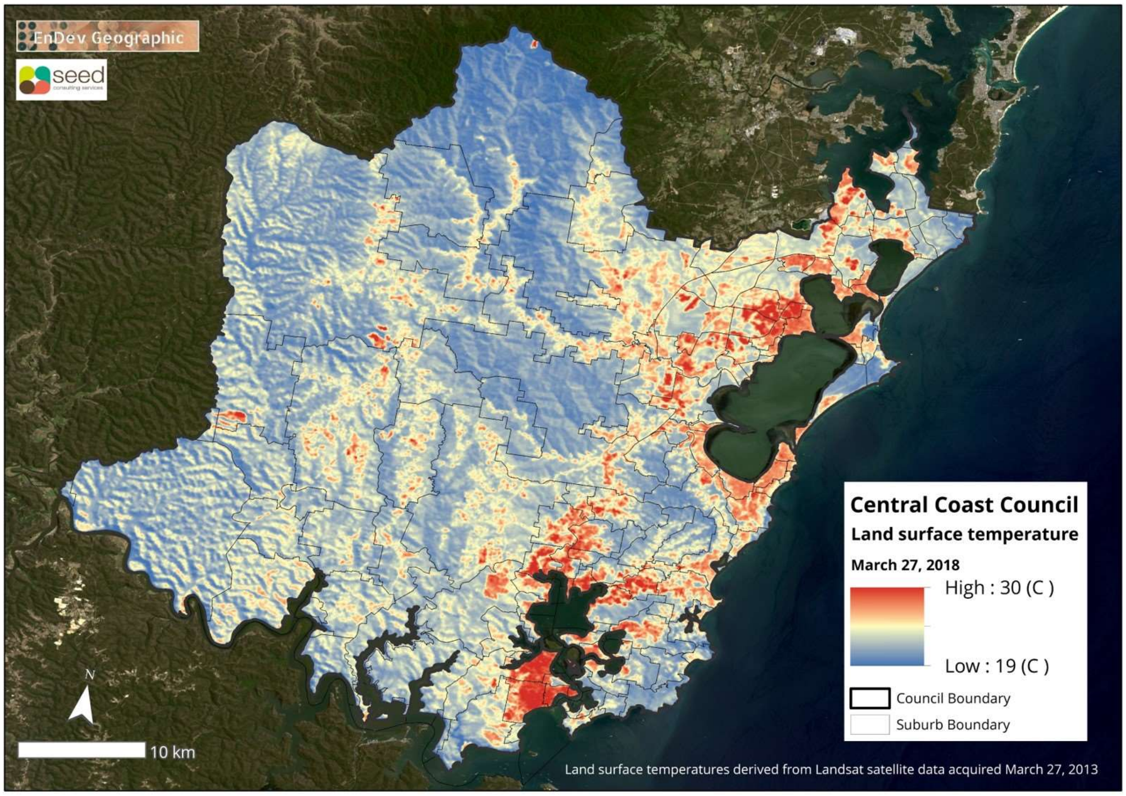


Figure 1. 2018 Land surface temperature map.

Table 1. 2018 Ten hottest suburbs.

Rank	Hottest Suburbs 2018	Temperature above baseline (ºC)
1st	ETTALONG BEACH	5.73
2nd	UMINA BEACH	4.38
3rd	BOOKER BAY	4.37
4th	WOONGARRAH	4.07
5th	BLUE HAVEN	4.00
6th	POINT FREDERICK	3.97
7th	EAST GOSFORD	3.97
8th	LAKE HAVEN	3.88
9th	WATANOBBI	3.80
10th	LONG JETTY	3.41

2.2.2 2018 Heat islands

The distribution of urban heat islands largely follows the patterns presented in the temperature map (Figure 2), but this is not always the case. Mixed-use areas that break up heat absorbing landscapes with cooling features such as green infrastructure and lighter coloured surfaces, can present localised hotspots that do not accumulate to larger heat islands. In this study, the most dominant heat island signal comes from the suburb of Long Jetty with over 90% of its area falling within a heat island (Table 2). Although it is only the 10th hottest suburb, its more homogenous land cover means there is little relief from the heat, whereas hotter suburbs have more concentrated heat islands. Heat islands pose a serious challenge in this area as the ten suburbs with the highest proportion of heat islands all have 80% or more of their area classifying as a heat island.

Within heat islands there often exists areas of further heat concentration, called extreme heat islands. Of the ten suburbs with the highest percentage of extreme heat islands, seven are also in the top ten hottest suburbs overall, suggesting extreme heat islands warrant more attention in considering heat mitigation options.

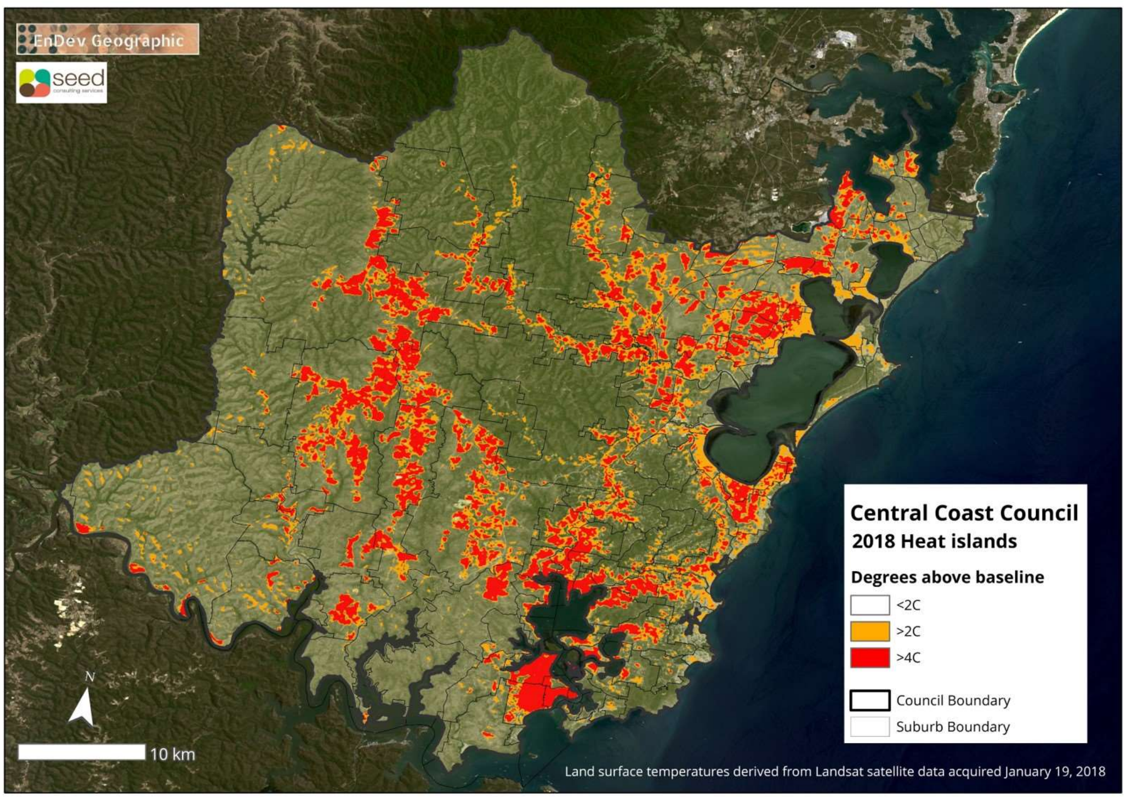


Figure 2. 2018 heat islands map.

Table 2. Suburb heat island ranking.

Rank	Suburbs with the highest proportion of heat islands 2018	Temperature above baseline (C)
1st	LONG JETTY	91.0%
2nd	LAKE HAVEN	88.9%
3rd	GOROKAN	87.0%
4th	WATANOBBI	86.8%
5th	WOONGARRAH	85.9%
6th	KILLARNEY VALE	83.5%
7th	UMINA BEACH	82.8%
8th	ETTALONG BEACH	81.1%
9th	BLUE HAVEN	79.9%
10th	KANWAL	79.7%

2.2.3 2013 Land surface temperature

Landscape temperatures in 2013 demonstrated a similar pattern of cool forests, warm cities, and mild coastal areas (Figure 3), but distinctly lacking the patterns of heat in the agricultural areas identified in 2018. As this data was collected in a different season—spring instead of march—it is likely that this signal is associated with a different phase of the crop cycle, more of a short-lived land cover change than a long-term land use change. Of the hottest suburbs in 2013, many are the same with 7 suburbs ranking in the top 10 both in 2013 and 2018 Table 3). The relationship with vegetation is a driving influence, with all 10 of the 2013 hottest suburbs falling in the bottom quartile of NDVI values.

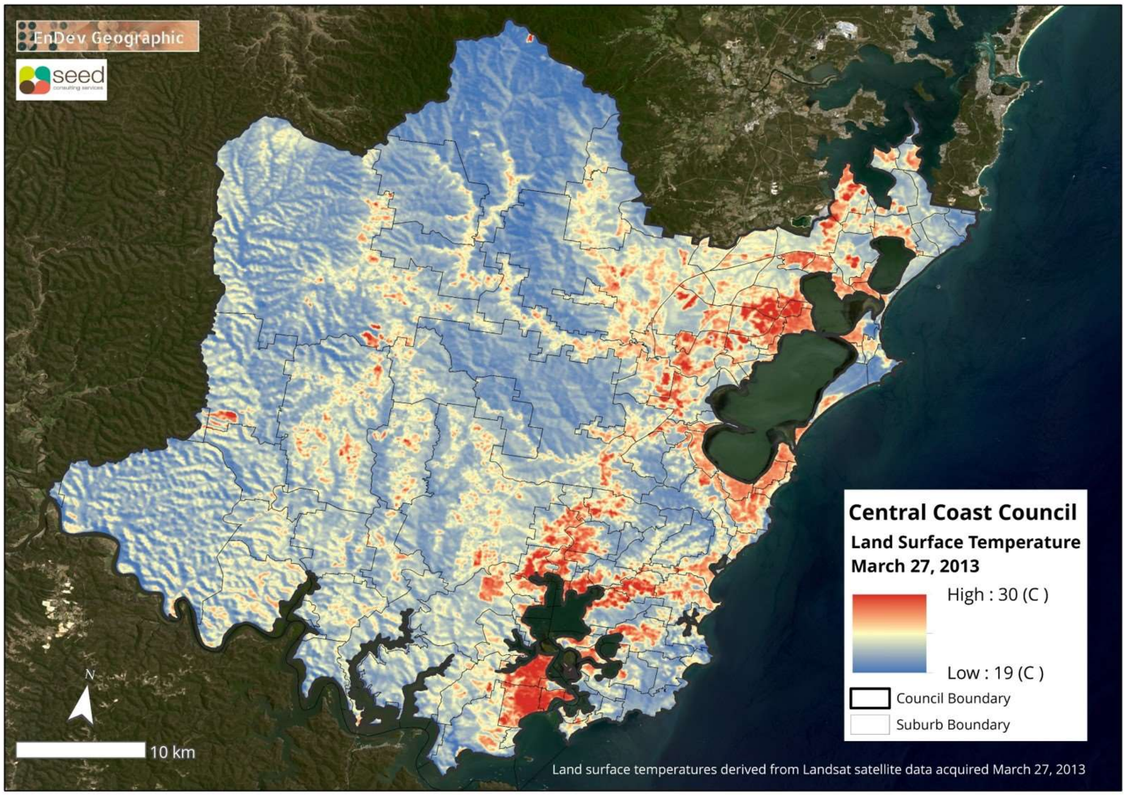


Figure 3. 2013 Land surface temperature map

Table 3. 2013 Ten hottest suburbs.

Rank	Hottest Suburbs 2013	Temperature above baseline (C)
1st	LAKE HAVEN	3.26
2nd	ETTALONG BEACH	3.16
3rd	UMINA BEACH	2.94
4th	BOOKER BAY	2.60
5th	GOROKAN	2.51
6th	KANWAL	2.28
7th	POINT FREDERICK	2.25
8th	LONG JETTY	2.23
9th	WATANOBBI	2.22
10th	WOONGARRAH	2.19

2.2.4 Change in thermal landscape 2013-2018

Assessing thermal landscapes over time reveals where changes have occurred and, knowing what actions have taken place in that area, allows a better understanding of the thermal impacts of land use decisions. Comparing the 2018 land surface data with the 2013 data reveals several patterns: major warming in the agricultural interior, warming in some urban areas, slight cooling along coastal areas, but with the majority of the area unchanged (Figure 4). The most dominant of these patterns, the warming of the agricultural interior is most likely a result of different phases in the crop cycle between January and March, as discussed previously.

While most suburbs fall in the middle, five suburbs were in the 10 hottest in 2013, 10 hottest in 2018, and were also in the 10 that warmed the most during that period: Ettalong Beach, Woongarrah, Booker Bay, Point Frederick, and Watanobbi. These suburbs may warrant additional, more localised assessment (Table 4).

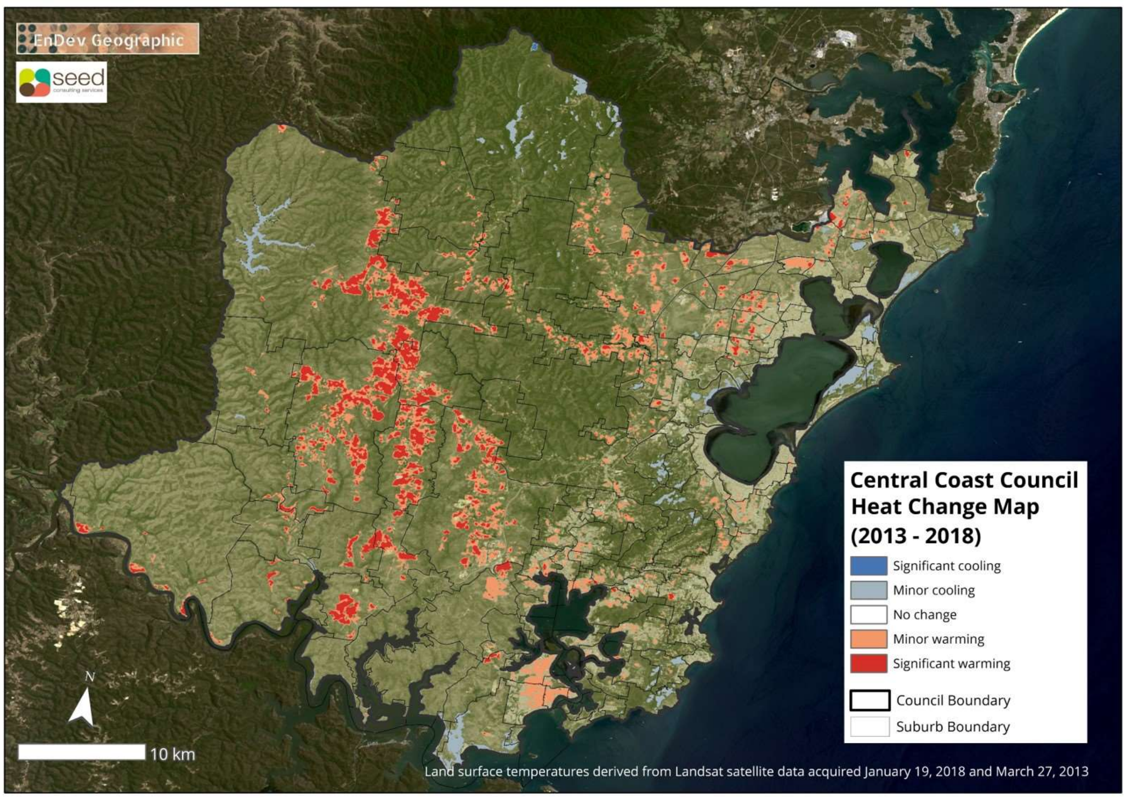


Figure 4. Heat change map 2013-2018.

Table 4. Suburbs experiencing the greatest warming between 2013 and 2018.

Rank	Suburbs experiencing the most warming between 2013 and 2018	Temperature increase (C)
1st	ETTALONG BEACH	2.57
2nd	ALISON	2.03
3rd	PEATS RIDGE	1.96
4th	BLUE HAVEN	1.88
5th	WOONGARRAH	1.88
6th	EAST GOSFORD	1.79
7th	BOOKER BAY	1.77
8th	KIAR	1.76
9th	POINT FREDERICK	1.72
10th	WATANOBBI	1.58

2.2.5 2018 NDVI

The Central Coast Council lies in a lush coastal region of New South Wales. On a scale of -1 (barren earth) to 1 (tropical rainforest), the mean NDVI value the Council registered at 0.34 verifies the heavy degree of vegetation. The 2018 NDVI map reveals a strong corridor of vegetation from Ravensdale, across western Jilliby, down through Ourimbah, and ending in Macham (Figure 5). The western region and other areas are heavily vegetated, but this NNW-SSE corridor appears particularly lush and holds all 10 of the suburbs with the highest NDVI values (Table 5).

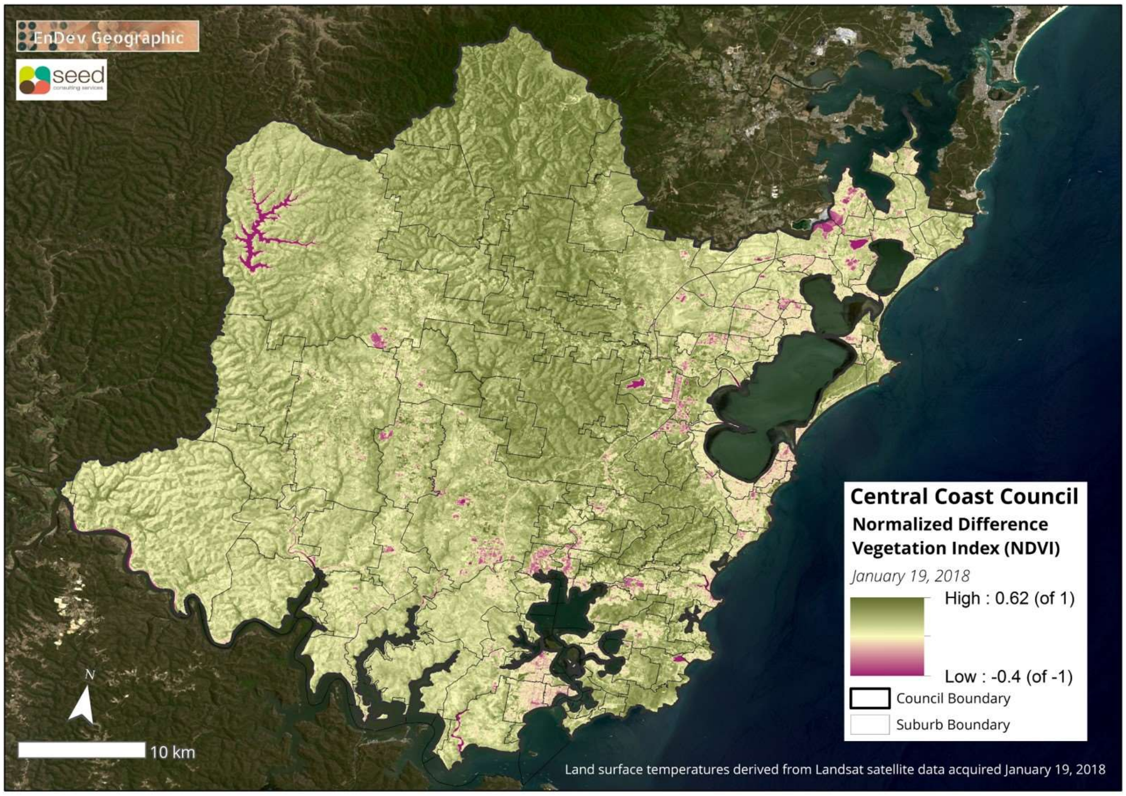


Figure 5. 2018 NDVI map.

Table 5. Suburb statistics of NDVI.

2018 Highest NDVI Suburbs				2013 Highest NDVI Suburbs			Greatest NDVI Change Suburbs (2013-2018)	
Rank	Suburb	2018 NDVI Mean Value (-1 to 1)		Suburb	2013 NDVI Mean Value (-1 to 1)		Suburb	NDVI Increase
1st	RAVENSDALE	0.43		LITTLE JILLIBY	0.40		WISEMANS FERRY	0.06
2nd	LEMON TREE	0.41		PALMDALE	0.39		RAVENSDALE	0.06
3rd	LITTLE JILLIBY	0.41		PICKETTS VALLEY	0.39		BOX HEAD	0.05
4th	PALM GROVE	0.41		WYONG CREEK	0.38		COGRA BAY	0.05
5th	HOLGATE	0.41		MATCHAM	0.38		LEMON TREE	0.04
6th	OURIMBAH	0.40		HOLGATE	0.38		TEN MILE HOLLOW	0.04
7th	CEDAR BRUSH CREEK	0.40		PALM GROVE	0.38		CEDAR BRUSH CREEK	0.04
8th	WYONG CREEK	0.40		GLENNING VALLEY	0.38		MARLOW	0.03
9th	MATCHAM	0.40		RAVENSDALE	0.37		PHEGANS BAY	0.03
10th	PALMDALE	0.39		MOUNT ELLIOT	0.37		PALM GROVE	0.03

2.2.6 Change in NDVI 2013-2018

To further understand the role of vegetation and green infrastructure in the changing thermal landscape, NDVI was also calculated from the 2013 data for comparison, resulting in an NDVI change map (Figure 6). Comparing NDVI from differing seasons presents challenges as the photosynthesis varies during different parts of the growing season. The biggest apparent change occurs in the “browning” of the agricultural region, again, most likely capturing different parts of the crop cycle, and the “vegetation corridor” appears to increase in lushness. However, the most useful aspect of the NDVI change map lies in the peri-urban area where purple areas identify locations that have shifted from *vegetated* to *built*. Land use change and build-out in suburbs such as Mount White, Terrigal, Hamlyn Terrace, Woongarrah, and Gwandalan are easily identifiable in the NDVI change analysis.

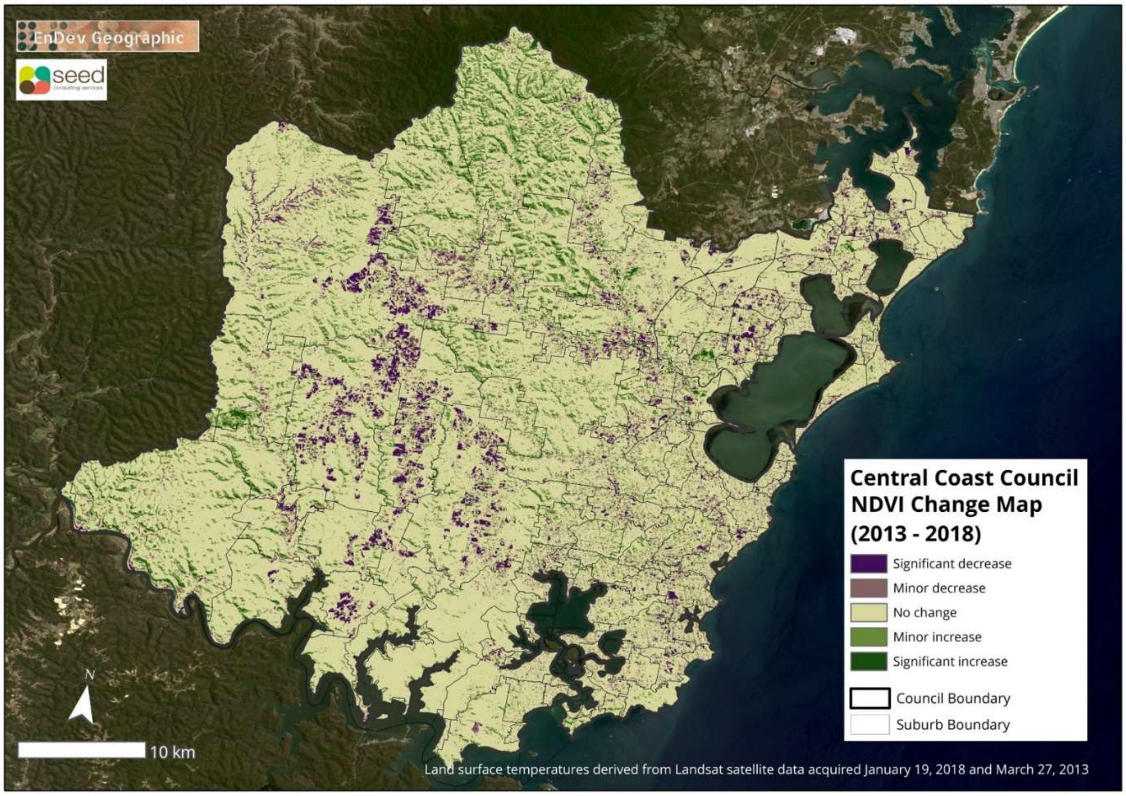


Figure 6. NDVI change map from 2013-2018.

2.2.7 Target suburbs

The 11 target suburbs identified for this analysis generally fall within the middle 50% of the range for all suburbs, across all included measures. Lake Haven does stand out as being the 8th warmest suburb, with Gosford, Erina, and The Entrance also falling in the top 25% of warmest suburbs (Table 6). These four suburbs also contain considerable heat islands with all of them having more than half of their areas registering more than 2 ºC above average. All of the target suburbs have moderate-high NDVI scores that barely changed between 2013 and 2018. Overall, these 11 suburbs do not standout from the broader area evaluated in this assessment.

Due to the limited resolution of the satellite-based data, maps of the target suburbs are presented in two groups corresponding to Southern (Figure 7 & Figure 8) and Northern Suburbs (Figure 10 & Figure 11).

Table 6. Suburb statistics of target suburbs

Suburb	*2018 Warmest Suburb Rank*	2018 Heat Islands (>2C) Coverage (%)	2018 Mean Temp *deviation from baseline* (ºC)	2013 Mean Temp *deviation from baseline* (ºC)	*Temp Increase Rank*	2018 NDVI Mean Value (-1 to 1)	Change in Mean NDVI between 2013 and 2018
ERINA	*17th*	66.6%	3.05	2.00	*26th*	0.27	0.00
GOSFORD	*14th*	63.8%	3.21	1.89	*15th*	0.25	0.00
KARIONG	*71st*	15.5%	0.74	0.33	*55th*	0.30	0.01
TERRIGAL	*41st*	48.9%	1.66	1.15	*43rd*	0.29	-0.01
WOY WOY	*38th*	30.7%	1.74	1.28	*50th*	0.28	0.01
LAKE HAVEN	*8th*	88.9%	3.88	3.26	*37th*	0.21	-0.01
THE ENTRANCE	*24th*	70.9%	2.50	1.90	*38th*	0.18	0.00
TUGGERAH	*78th*	33.7%	0.53	1.10	*109th*	0.30	0.01
TOUKLEY	*116th*	30.0%	-0.76	0.66	*140th*	0.27	0.02
WARNERVALE	*66th*	35.5%	0.87	0.84	*77th*	0.30	0.02
WYONG	*39th*	48.9%	1.70	1.36	*64th*	0.30	0.03

2.2.7.1 Southern suburbs

The southern target suburbs include Erina, Gosford, Kariong, Terrigal, and Woy Woy. A colour imagery map is presented (Figure 7) to provide the context for interpreting the 2018 urban heat map (Figure 8).

In Erina, a clear pattern of heat is demonstrated by the Erina Fair Shopping Centre. The large swath of impervious buildings and carparks produce a clear heat island signal (Figure 9). Although the shopping centre is mainly covered with white roofs which reflect some of the heat, the surrounding bitumen cark parks and buildings themselves absorb heat with the dark parking lot to the north of the centre being the hottest location in Erina. By contrast, the extensive green spaces surrounding the shopping centre are some of the coolest in the suburb and provide a substantial break on the heat island. Erina on average measured 3 ºC above baseline, with two thirds of its land classifying as a heat island with the shopping centre being the largest (Table 6). Figure 9 illustrates the effectiveness of satellite data in capturing landscape scale patterns of land uses and their general influences on heat, but also demonstrates the limitations imposed by the resolution of the satellite imagery whereby the influence of small and medium features are unresolvable.

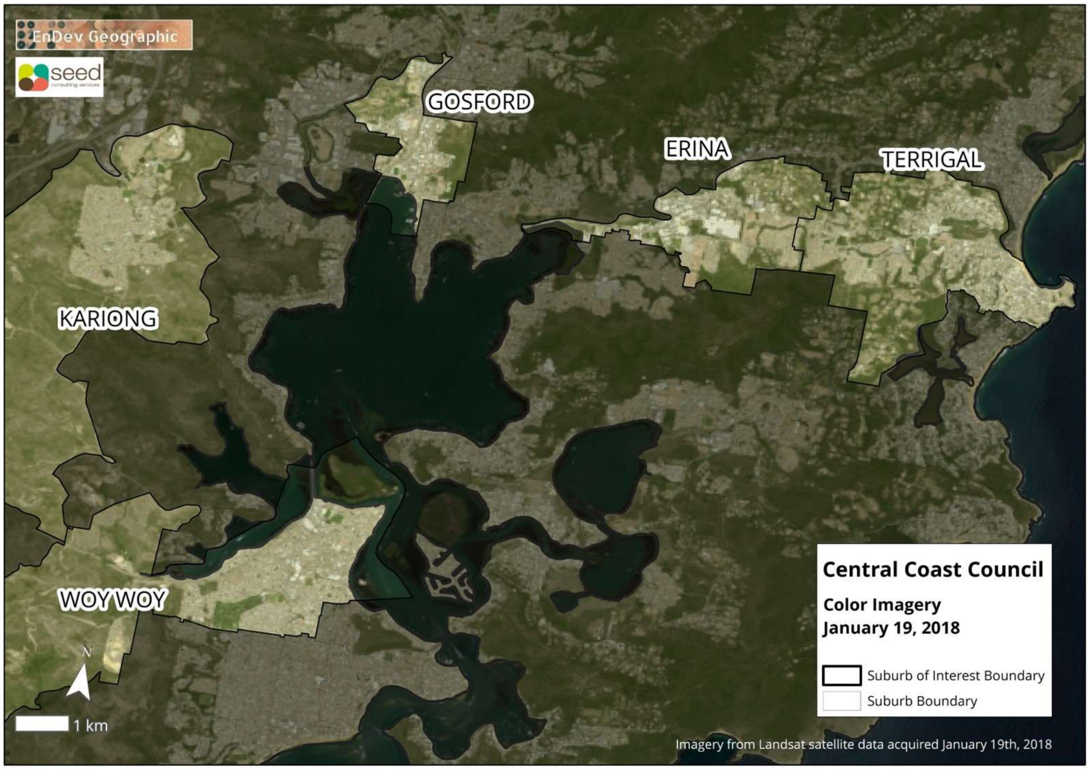


Figure 7. Colour imagery map of the southern target suburbs.

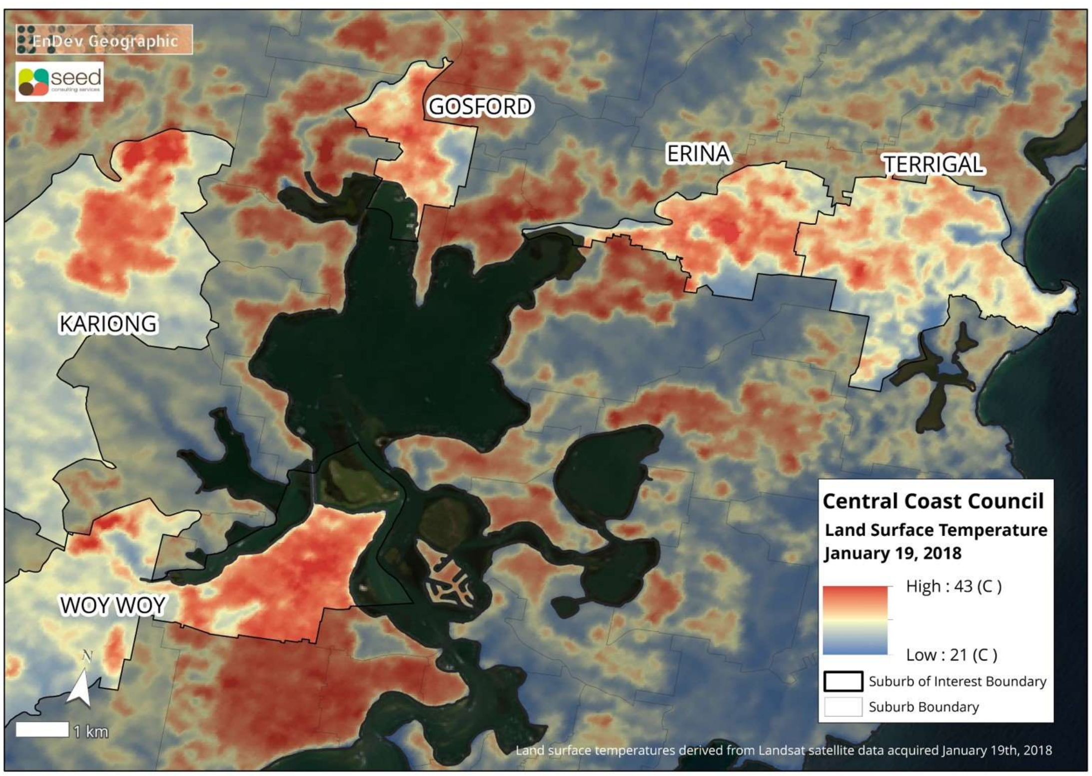


Figure 8. 2018 Land surface temperature map of the southern target suburbs.

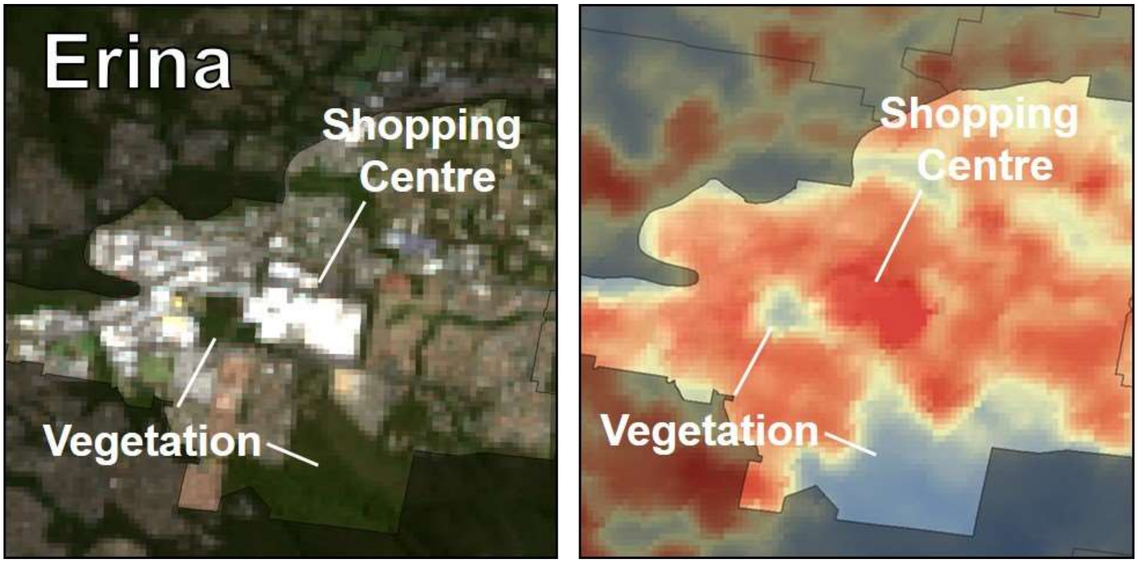


Figure 9. Erina suburb satellite colour image (left) and land surface temperature (right).

Gosford is the hottest of the southern target suburbs measuring 3.2 ^{o}C above baseline temperature with over 60% of its land falling under a heat island (Table 6). Most notably, compared to 2013, the average surface temperature in Gosford has increased by 1.3 ^{o}C. This rate of warming is the 15th highest among suburbs in the Central Coast Council. The warmest location is the Gosford Hospital and the surrounding area which has exhibited some continued warming since 2013. Rumbalara Reserve, along the east side of the suburb, is the coolest areas followed by Gosford City Park along the waterfront.

Kariong, on average, generally falls within the surface temperature range of most councils (<1 ^{o}C above background) on account of its large vegetated areas to the west, though it has warmed by 0.5 ^{o}C over the last 5 years. The pattern of warming, however, is highly unequal, all of the warming occurring in the urban areas which exhibited >3 ^{o}C of surface warming during that same period.

Terrigal, though slightly warmer than Kariong, demonstrated a very similar pattern of ~0.5 ^{o}C of warming over the last 5 years. The primary driver of this heat is the new residential development in the south west quadrant of the suburb, south of Kings Avenue, where large areas have been transformed from natural to built environments which has now become the hottest area in the suburb. This pattern is also present in the NDVI change map. The rest of Terrigal is moderated by vegetated areas to the south and interspersed through-out, and the cooling effect of the ocean to the east.

Woy Woy also has two distinct lobes of heat, with warmer urban areas to the east and cooler vegetated areas to the west. The eastern lobe is primarily residential with some commercial areas to the north. The NDVI change map shows some loss of vegetation evenly distributed across this area. The temperature change map shows that many of these same areas have warmed during that same time period, however areas closer to the water have experienced less warming.

2.2.7.2 Northern suburbs

The northern target suburbs include Lake Haven, The Entrance, Toukley, Tuggerah, Warnervale, and Wyong. Colour images of these areas are presented (Figure 10) to provide the context for interpreting the 2018 urban heat map (Figure 11).

Lake Haven is one of the hottest suburbs in the Central Coast Council measuring nearly 4^{o}C above baseline (Table 6). Lake Haven has continued to warm over the last 5 years, with warming occurring evenly across the area causing nearly 90% of its area to classify as a heat island. The high surface temperature in Lake Haven corresponds to limited vegetation (as measured through NDVI, Table 6) and the warming corresponds to a slight decrease in vegetation over the last 5 years. However, some cooling areas are present along the waterfront areas.

Similarly, The Entrance has one of the lowest levels of cooling vegetation, while averaging 2.5^{o}C above baseline temperature; a pattern that would likely be much worse if it weren't surrounded by water on three sides. A small cool area exists around the oval at the centre of town and immediately along the ocean shoreline, but otherwise heat builds up over the predominately dark rooved residential areas of The Entrance.

The commercial corridor of Tuggerah presents a steady signal of urban with as the large buildings and dark carparks trap absorb and re-radiate heat. The Tuggerah Super Centre sits at the centre of this urban heat island. Overall, Tuggerah has a substantial mix of green space which helps offset that heat and only one third of its land falling under a heat island, and exhibited a cooling between 2013 and 2018 driven by cooling in the forested area along the water front.

Toukley is the only one of the targeted suburbs that measured cooler than baseline on account of its large forested areas, proximity to the ocean, and extensive waterside (Figure 12). Toukley has a high fraction of vegetation, the health of which appears to have increased over the last 5 years. The golf course also provides a cooling benefit though not as strong as the closed canopy forest. The residential and commercial precinct, while warmer than baseline, averaged less than 1^{o}C above baseline making it one of the cooler developed areas.

The two hottest areas in Warnervale are the airport and the industrial precinct (Figure 13). The airport averaged 6^{o}C above baseline while the industrial areas averaged 5^{o}C above baseline. While significant, this heat is isolated to small pockets that are removed from residential areas which restricts exposure mainly to employees of those areas and they interspersed with heavily vegetated areas which minimizes their contribution to larger heat islands. The heavily vegetated cool areas are broken by an area of open ground with little vegetation which further concentrates heat in the areas surrounding the built environment.

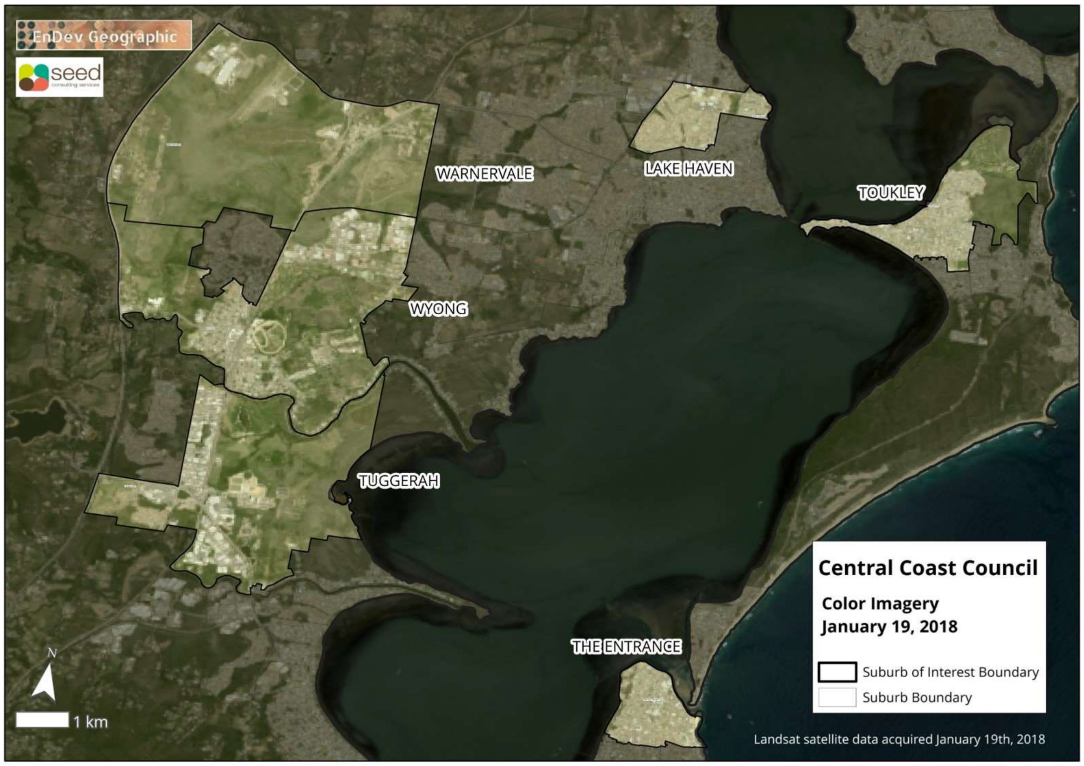


Figure 10. Colour imagery of the northern target suburbs.

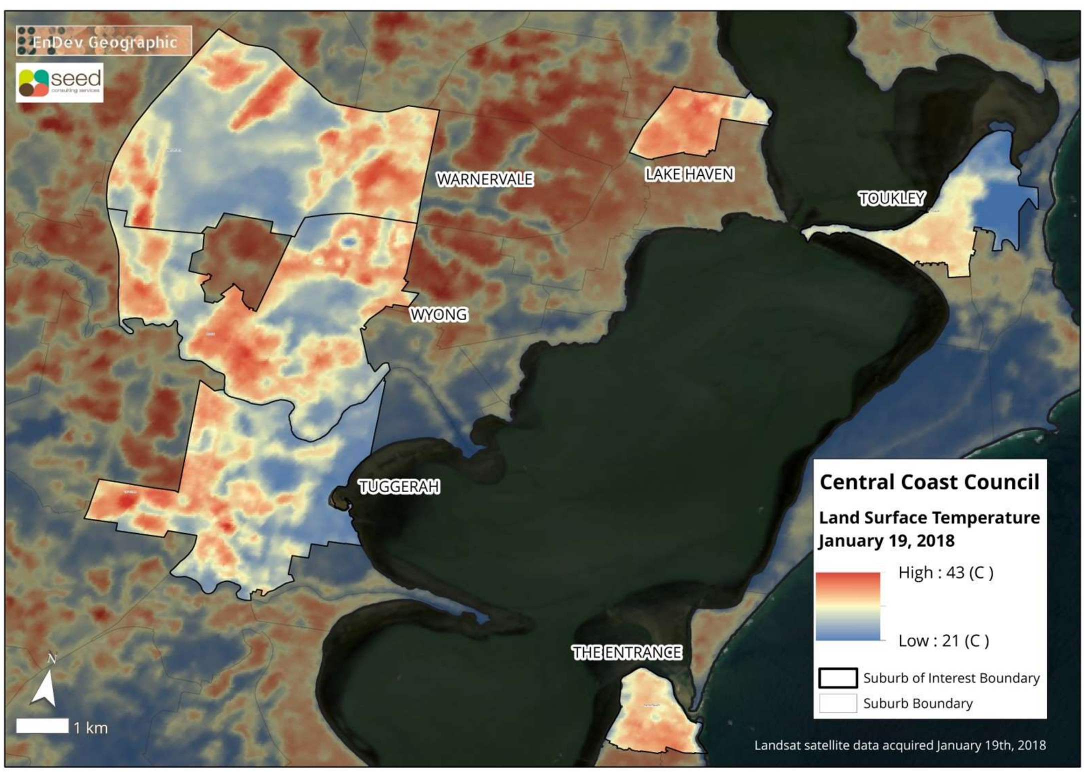


Figure 11. 2018 Land surface temperature map of the northern target suburbs.

seed consulting services

Figure 12. Toukley colour image (left) and land surface temperature (right).

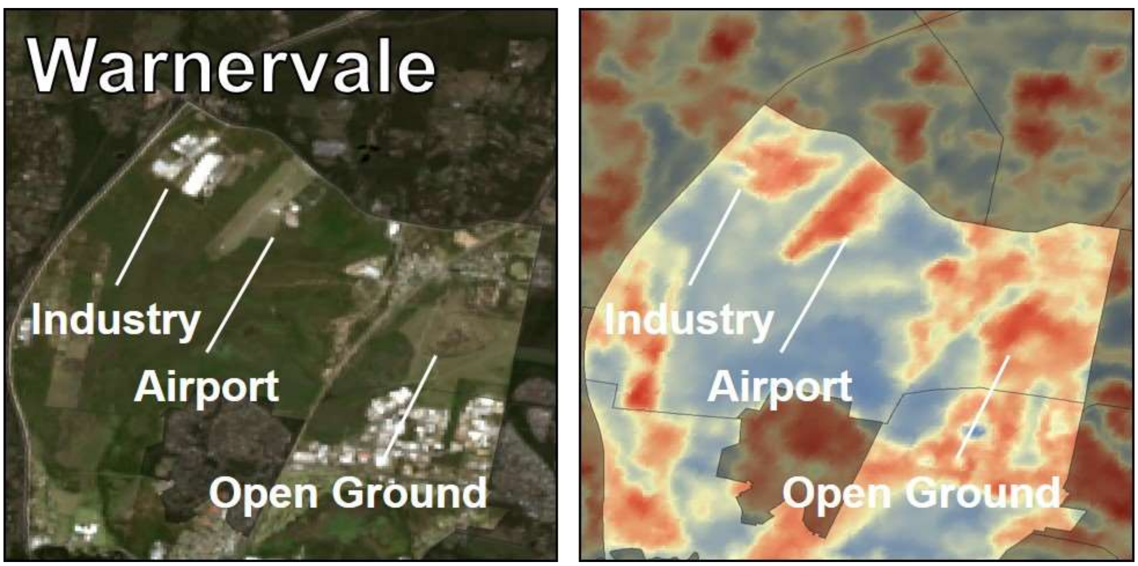


Figure 13. Warnervale colour image (left) and land surface temperature (right).

The broader Wyong suburb presents a mix of forest, farm, and urban space. On average, it measures 1.7 ºC above baseline, but considering most of the vegetated lands are cooler than average, the heat is heavily concentrated in the urban areas. Specifically, heat is centred around Wyong Station and tracks to the northwest and southeast until it encounters vegetated lands.

2.2.8 Limitations

The two datasets were both collected on warm days as verified with Bureau of Meteorology data. While thermal conditions were similar on the two days, landscapes are also conditioned by the temperature and precipitation of the preceding month. As such, a late March collection likely captures a different temperature and precipitation regime, and therefore thermal data and vegetation may present differently. Appropriate consideration should be applied in extrapolating patterns of change from two different seasonal timepoints. Additionally, satellite data measures land surface temperature which is a direct influence on air temperature, but other factors also bear influence. For example, different prevailing winds can be responsible for differences between air and land surface temperature, especially in coastal settings.

This analysis is conducted at the suburb and council scale which is ideal for assessing landscape scale patterns. However, summarizing data to this scale can overlook some patterns, especially when aerial units are of varying size. For example, the suburb of Woy Woy contains two lobes, one urban (eastern) and one vegetated (western). Considered individually, the urban lobe may be one of the hottest in the council but combined it does not register as abnormally hot.

Satellite data provide a broad vantage point, capturing large areas at a single time-point which allows for direct comparison of the heat impacts across the whole of the city. However, there are three primary limitations to using satellite data. The first limitation is the resolution of Landsat data which for thermal data is $100m^2$, meaning that the heat signal from any feature smaller than this is merged with neighboring features. This resolution is suitable for identifying the temperature of large parking lots, but will not clearly identify the temperature of individual roads. As such, Landsat is ideal for large, landscape and city scales studies, but encounters difficulty in determining the heat contribution of smaller features.

The second limitation stems from the fixed orbit the Landsat satellite which results in an 11:05AM overpass. Late morning is ideal for clear sky captures of colour imagery, but is sub-optimal for thermal data capture which is best suited to late afternoon capture. The third limitation is date selection. Satellites pass overhead on set days, (every 16 days for Landsat) irrespective of weather. This study relied on Landsat overpasses that coincided with warm days. Originally, the study intended to compare a decade-long timeseries, but data coverage and quality of 2008 were not suitable for this analysis, leading to the 5-year timeseries.

These limitations are inherent products of satellite-based studies. Circumventing these limitations requires selecting a more adaptable platform for collecting thermal data, such as airborne or UAV-based sensing. Airborne data collection can cover similar areas at much higher resolution and can be tasked to fly at optimal times and dates, providing much greater detail and answering more specific questions.

3 Urban Canopy Cover

3.1 Approach and method

3.1.1 Focal suburbs

The primary focus of this project was to investigate urban land cover, particularly canopy cover, in order to facilitate urban planning and strategic decision making. Council identified 94 (61%) of their suburbs as falling within the urban footprint (Table 7, Figure 14), forming the basis of this project. The remaining suburbs were considered more rural than urban and were not included in the land cover analyses. Analyses were conducted at the suburb scale and these results combined to provide “urban wide” results for the Council area.

3.1.2 i-Tree Canopy

Land cover was analysed using the i-Tree Canopy software[1] which allows a user to readily, and statistically rigorously, classify land cover amounts within a user-defined area overlaid on Google Earth imagery. As each point is classified, i-Tree Canopy provides automated running statistical estimates for land cover categories of the estimate total area (km^2) and percent cover (%) within the study area, as well as an uncertainty estimate (i.e. standard error, SE). Generally, the more points that are classified, the lower the standard error and the more precise the estimated result should be. However, the more land-cover categories defined, the more points that need to be classified in order to achieve statistical stabilisation of estimates (Jacobs, et al., 2014).

i-Tree Canopy suggests surveying 500-1000 points per sample area, though the difference in resources required to survey 500 points versus 1000 points can be substantial when multiple areas are involved, with potentially little gain in precision and varying levels of confidence in the outputs. The authors of Australia’s national canopy benchmarking report undertook further evaluations and found that between 600-1000 points would tend to provide a standard error of <3%[7]. However, this again would result in varying confidence levels in outputs given the varying sampling intensity among larger and smaller areas (i.e. likely lower confidence levels for larger areas, and higher for smaller areas).

For this project, a power analysis was conducted *a priori* to determine how the number of survey points per suburb would vary given differing confidence levels (CL) and confidence intervals (CI). The outputs indicate the number of points which would achieve statistically acceptable levels of error among suburbs of varying sizes whilst limiting the potential for surveying more points than necessary to produce fit-for-purpose outputs.

With a need to achieve a balance between limited resourcing and acceptable levels of statistical error, the Central Coast Council selected a 95% CL and 5% CI, which equated to 384 points per suburb. The way to relate these power analyses to the assessment outputs is, for example: based on the 384 points surveyed in each suburb, if the assessment outputs estimate a canopy cover of 25% then we are at least 95% confident that the actual canopy

[1] https://canopy.itreetools.org/

cover across the city is between 20% and 30% (i.e. estimated output plus or minus the 5% confidence interval). To greatly improve on these confidence levels and intervals significantly more points would need to be surveyed. However, statistically and for the requirements of this project, this level of power is considered acceptable.

Note that the urban-wide assessments are based on the collation of the suburb-level assessments and therefore are based on a total of 36,096 points, which roughly equates to a 95% CL and a 0.5% CI.

Table 7. The 94 suburbs, and their areas, assessed for this project (see also Figure 14).

SUBURB	Area (km2)	SUBURB	Area (km2)	SUBURB	Area (km2)
Avoca Beach	5.20	Horsfield Bay	0.54	Saratoga	4.69
Bateau Bay	8.70	Kanwal	3.03	Shelly Beach	1.42
Bensville	6.67	Kariong	30.84	Springfield	5.48
Berkeley Vale	7.33	Kilarney Vale	3.64	St Huberts Island	3.26
Blackwall	1.92	Killcare	2.98	Summerland Point	3.78
Blue Bay	0.64	Killcare Heights	2.62	Tacoma	2.81
Blue Haven	3.06	Kincumber	12.33	Tacoma South	1.61
Booker Bay	1.23	Kincumber South	2.76	Tascott	4.37
Budgewoi	3.73	Koolewong	4.20	Terrigal	10.98
Buff Point	2.46	Lake Haven	2.07	The Entrance	1.96
Canton Beach	1.02	Lake Munmorah	6.65	The Entrance North	1.26
Chain Valley Bay	7.10	Lisarow	13.03	Toowoon Bay	0.72
Charmhaven	8.35	Long Jetty	3.05	Toukley	4.08
Chittaway Bay	1.31	MacMasters Beach	6.51	Tuggerah	11.58
Chittaway Point	1.88	Magenta	8.36	Tuggerawong	1.84
Copacabana	2.48	Mannering Park	8.89	Tumbi Umbi	15.44
Daleys Point	2.25	Mardi	11.26	Umina Beach	8.38
Davistown	2.82	Narara	10.00	Wadalba	4.41
East Gosford	2.44	Niagara Park	4.52	Wagstaffe	0.93
Empire Bay	6.77	Norah Head	4.63	Wamberal	10.58
Erina	6.21	Noraville	2.36	Warnervale	15.43
Ettalong Beach	2.55	North Avoca	2.08	Wattanobbi	2.13
Forresters Beach	3.39	North Gosford	2.28	West Gosford	6.41
Glenning Valley	6.79	Ourimbah	104.89	Woongarrah	6.33
Gorokan	3.63	Patonga	35.89	Woy Woy	22.90
Gosford	4.10	Pearl Beach	1.50	Woy Woy Bay	10.65
Green Point	18.27	Phegans Bay	0.78	Wyoming	8.60
Gwandalan	3.77	Point Clare	5.57	Wyong	13.52
Halekulani	1.75	Point Frederick	1.42	Wyongah	1.24
Halloran	3.49	Pretty Beach	1.13	Yattalunga	0.93
Hamlyn Terrace	6.27	Rocky Point	0.16		
Hardys Bay	0.71	San Remo	2.74		

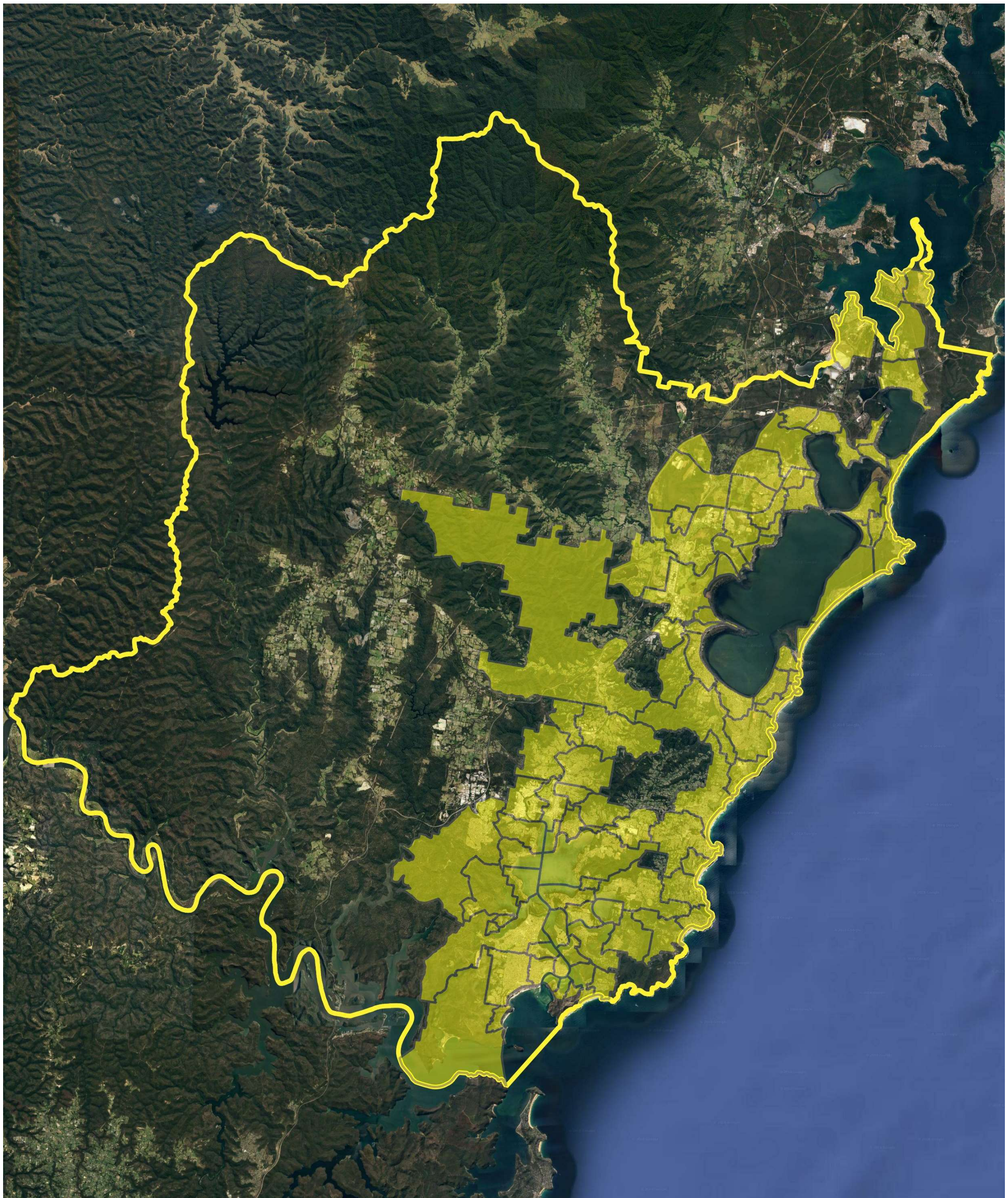


Figure 14. Suburbs assessed for urban canopy cover

N

Scale @ A4
1: 350,000

Note: (i) this map is not guaranteed to be free from error or omissions, and has been produced for the exclusive use of the Client and Seed Consulting Services (ii) Contours accuracy has not been verified and no reliance should be placed upon them for any purpose other than the original purpose of this map (iii) Aerial photos and satellite imagery have been overlaid as best fit on the boundaries shown and precision is approximate only (iv) Scale shown is correct for original map and any copies of this map should be verified by checking against the scale provided (v) This figure may not be copied unless this not is included.

Last updated: 15/10/18 Drawn: JG
Ref:. 856_Canopy_Fig1 Datum: GDA94
Data source/s: Central Coast Council
Imagery: Google Earth 2018

3.1.3 Land cover categories

Thirteen land cover categories were used to assess each of the points. These categories were based on similar assessments conducted for other local Council areas in Queensland and South Australia (Table 8; Plate 1).

3.1.4 Assessment errors and considerations

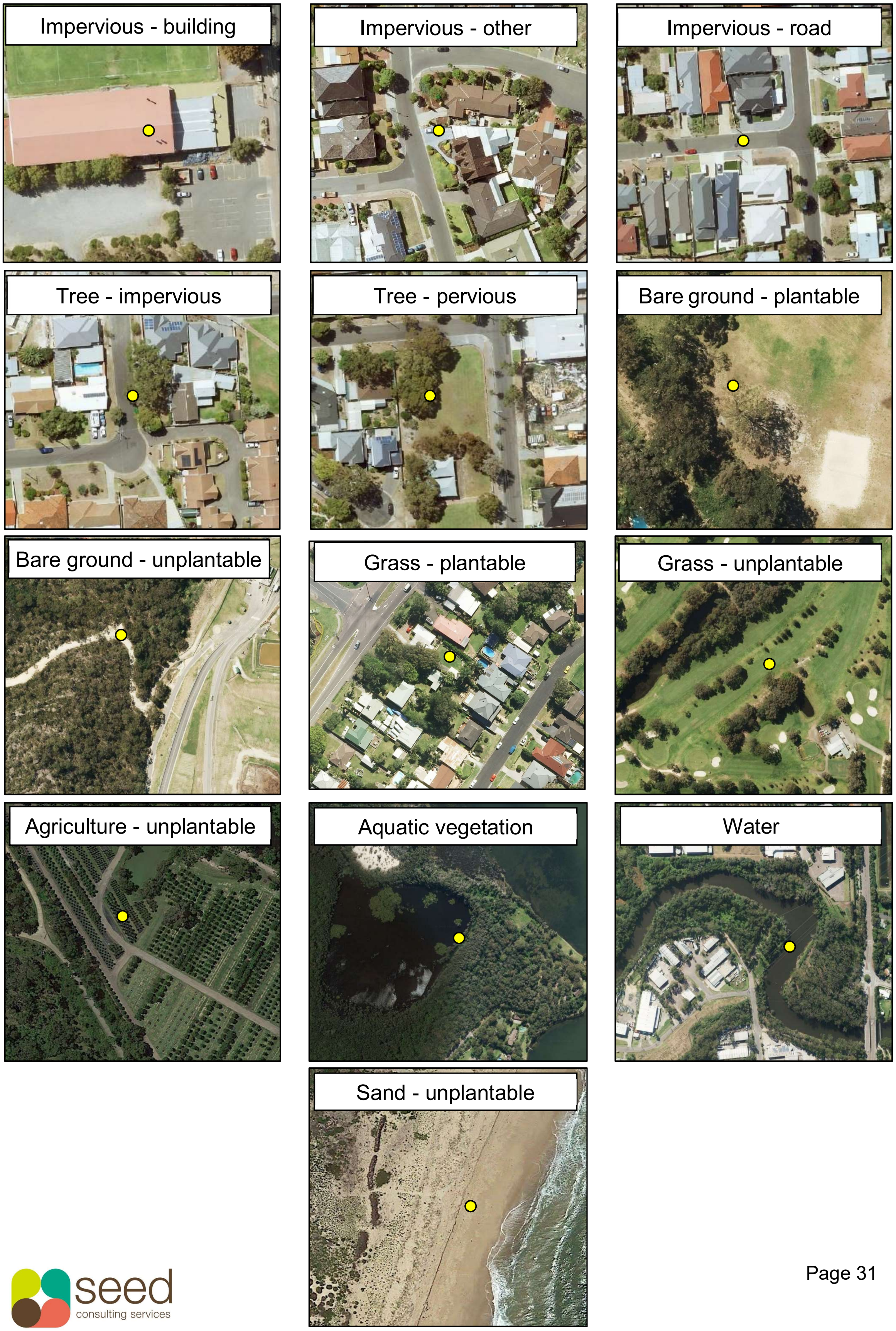
The interpretation of satellite imagery and aerial photos is open to interpretation by the user, which may lead to an inherent level of error in the land cover classification, particularly if the quality of the imagery/photo is poor. Such error was minimized as much as possible by considering the surrounding land use context and comparing images in other time periods. Key interpretation issues that may be faced in such analyses include:

- Non-anthropogenic land-cover changes:
    - seasonal variations may result in a point's land-cover category changing between different assessment dates. For example, a point classified as "grass other" in one year/month may be classified as "bare ground" in another year/month due to changes only caused by seasonal influences. Other similar changes may occur due to fluctuations in water levels in waterways and water bodies;
- Inferred points:
    - user-rationale was used to interpret land cover under points where shadows impeded a clear view; where necessary, comparison with imagery from other time periods and Google street view were also assessed;
    - where a point fell over a temporary cover (e.g. cars, junkyard debris), the more permanent land cover is classified. For example, a point falling over a car parked on a grassy area, would be classified as "grass" not "impervious". Similarly, a point falling over a boat on the water would be classified as "water";
- Photo skew and quality:
    - the quality of aerial photos and satellite imagery (particularly older images) can vary substantially in quality and resolution and influence the ability to clearly identify land cover; and
    - aerial photos can appear displaced or skewed due to variation in the capture angles of the aircraft/satellite relative to the feature. This displacement increases as the look angle moves away from a vertical capture angle, and so features at the edge of an image will have more displacement than those directly below the sensor at the time of acquisition. When these photos are georeferenced, this skew can impact on where certain points appear to fall. User interpretation is required in these cases to infer how the photo would appear if not displaced/skewed.

Table 8. Land cover categories used for i-Tree Canopy analysis. Categories used in this analysis were consistently applied irrespective of tenure (i.e. public or private land). See also Plate 1.

CATEGORY	CODE	DESCRIPTION
IMPERVIOUS		
Impervious – building	IB	A permanent built structure (e.g. house, carport, shed). Residential, commercial, industrial, public or any other.
Impervious – other	IO	Impervious surfaces not included in building and road cover classes. Includes footpaths, driveways, sports courts, swimming pools, fences, water features and perceived temporary structures (e.g. shade sails).
Impervious – road	IR	A sealed road, highway, service lane, airport runways, railway lines, light rail, car park. Excludes unsealed roads/tracks/carparks.
TREE CANOPY COVER		
Tree – impervious	TI	Tree canopy over perceived impervious surface. All trees obviously located within impervious surface.
Tree – pervious	TP	Tree canopy over perceived pervious surface. Includes mangroves, native forest, plantation, park trees.
PLANTABLE SPACE		
Bare ground	PBG	Non-vegetated pervious surface with tree planting potential. Includes areas of erosion. Excludes bare ground between agricultural plantings.
Grass	PG	Grassed areas with tree planting potential. Includes public parks, private lawns and areas beside active portion of sporting fields, as well as non-tree plants (e.g. shrubs and short hedges), pasture, grasslands.
UNPLANTABLE SPACE		
Agriculture	UA	Active cropping or other agricultural activity. Includes tree crops, sugar cane, vegetables, tilled paddocks, and aquaculture ponds. Includes bare ground between agricultural plantings.
Bare ground	UBG	Non-vegetated, non-plantable pervious surfaces. Includes earthworks, cliffs, extractive industries (quarries), beach rock, sand traps in golf courses, unsealed tracks/roads/driveways, carparks, and horse running tracks. Excludes bare ground between agricultural plantings.
Grass	UG	Grassed areas that are not plantable. Includes sporting fields, school ovals, golf fairways, putting greens, grass airport runways, and grass cover associated with extractive industries.
Sand	US	Non-vegetated portion of coastal sandy beaches and mudflats, to low tide mark. Usually adjacent to wetlands, mudflats and coasts.
Aquatic vegetation	UV	Vegetation growing on coastal sand dunes or around wetlands and waterways. Areas where achieving canopy cover is not likely due to environmental constraints (e.g. saltwater intrusion). Includes fringing or aquatic vegetation (not trees) associated with waterbodies, sedge lands, saltmarsh.
Water	W	Aquatic & marine waterbodies. Includes rivers, creeks, estuaries, canals, lakes, dams, marina, quarry water pits. Does not include pools.

Plate 1. Aerial images showing examples of each land cover category under a randomly allocated point (yellow dot).



3.1.5 Case study - historical canopy change assessment

As a case study, historical land cover within Woy Woy was assessed using 2005 aerial imagery provided by Council. The points for this suburb were converted to a GIS shapefile and overlaid on the historical imagery. The current classified land cover categories were visually compared to land cover in the 2005 aerial imagery. Using the i-Tree Canopy "change survey" function, land cover classifications for each point were reclassified as required to match 2005 land cover. The revised classifications in i-Tree Canopy were saved as new project files to enable future comparisons.

Examination of percent land cover change over time was conducted using a GIS and Excel to conduct additional spatial and statistical analyses based on the i-Tree Canopy land cover assessments. Change in percent land cover over time was assessed by comparing in Excel the difference in percent land cover between 2005 and current.

3.2 Urban canopy cover results

3.2.1 Across the urban area

The 94 suburbs assessed covered an area of 628.8km^2 (land and water area), representing approximately 30% of the total Central Coast Council area (land and water). Suburbs ranged in size from Rocky Point at 0.16km^2 to Ourimbah at 104.9km^2 (Table 1, Figure 15). A total of 36,096 points were assessed across all suburbs.

Across the 94 suburbs, hereafter referred to collectively as the "urban area", tree canopy was the dominant land cover type, covering nearly 42% (264km^2) of the urban area (Figure 16). The percent cover of impervious surfaces was roughly equal to the percent cover of plantable space, with both at nearly 21% (131km^2) (Figure 13). Unplantable surfaces comprised the remaining 16% of the urban area, equal to approximately 102km^2 (Figure 16).

Canopy cover predominantly occurred over pervious rather than impervious surfaces (38.54%, 242.4km^2 and 3.39%, 21.3km^2, respectively) (Figure 16). This is likely driven by the relatively large proportions of treed reserves and ranges which are either protected or unsuitable for development or agriculture. Approximately half of all impervious cover was attributed to buildings (60km^2), with roads and other impervious surfaces (e.g. footpaths, driveways, car parks, pools) each comprising approximately a quarter of the total impervious cover (5%, 31.4km^2 and 6.42%, 40.4km^2, respectively) (Figure 16). Bare ground and grassed areas considered to be potentially plantable with trees represent a substantial opportunity for increasing canopy cover within the urban areas. Almost all of the plantable space are currently grassy areas rather than bare ground (18.62%,117 km^2 and 2.25%, 14.1 km^2, respectively) (Figure 16). The proportion of plantable space on Council owned and managed land, however, may be significantly lower, if tenure patterns in Central Coast Council follow those seen in many urban councils, worldwide. Water and associated aquatic vegetation represented most of the areas considered to be unplantable (together, 12.11%, 76.1 km^2) (Figure 16), with unplantable bare ground covering approximately 2% of the urban area, equivalent to 12.6km^2. This unplantable bare ground is of particular interest as at least part of it may be due to the urban development works, which may in the future become impervious surfaces.

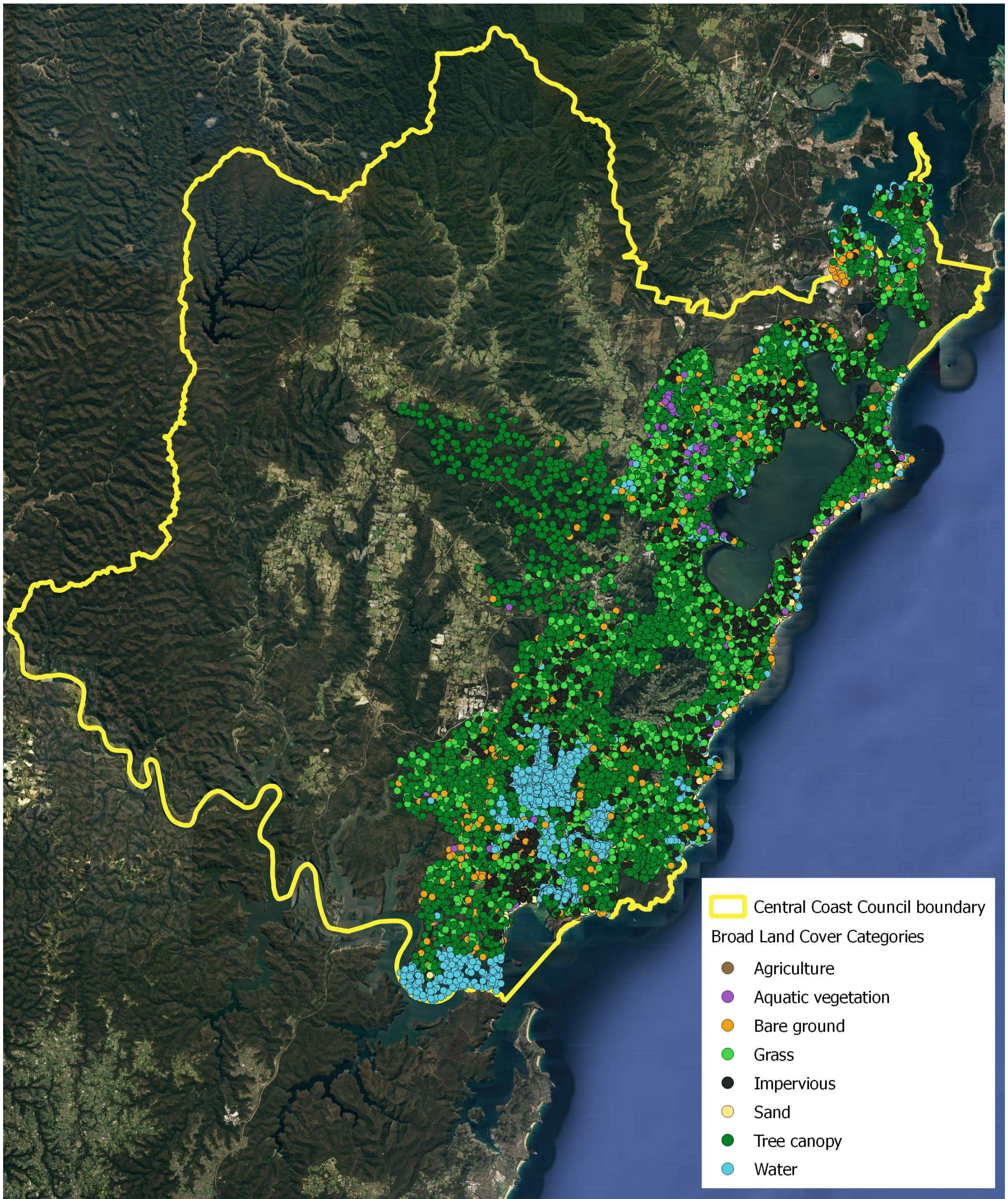


Figure 15. Assessment points covered by land cover.

N
Scale @ A4
1: 350,000

Note: (i) this map is not guaranteed to be free from error or omissions, and has been produced for the exclusive use of the Client and Seed Consulting Services (ii) Contours accuracy has not been verified and no reliance should be placed upon them for any purpose other than the original purpose of this map (iii) Aerial photos and satellite imagery have been overlaid as best fit on the boundaries shown and precision is approximate only (iv) Scale shown is correct for original map and any copies of this map should be verified by checking against the scale provided (v) This figure may not be copied unless this not is included.

Last updated: 15/10/18 Drawn: JG
Ref:. 856_Canopy_Fig2 Datum: GDA94
Data source/s: Central Coast Council; Seed Consulting Services
Imagery: Google Earth 2018

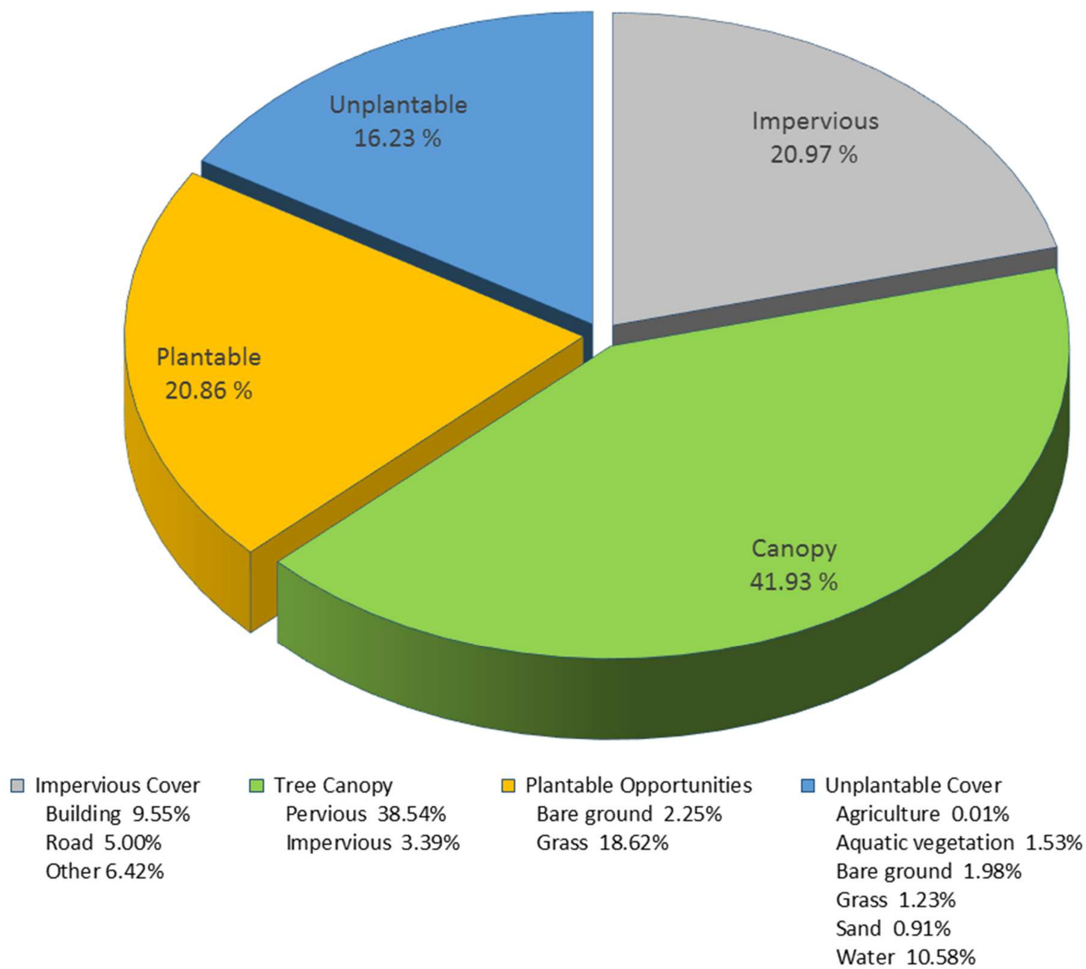


Figure 16. Estimated current land cover across the urban areas (94 suburbs) of Central Coast Council.

3.2.2 Suburb specific trends

Current land cover trends varied substantially among the 94 suburbs assessed (Figure 17 and Figure 18). Whilst all suburbs contained a mixture of impervious, canopy, plantable space, and unplantable cover, the proportions of land cover varied. Full details of land cover amounts for each suburb are provided in Appendix A.

Impervious cover ranged from 0.52% (0.19km^2) in Patonga to more than 50% in both Long Jetty and Lake Haven (1.55 km^2 and 1.05 km^2). However, given the range of size across suburbs, from a total area perspective, Woy Woy contained the greatest area of imperious cover at 3.94km^2 (17.19%) followed by Umina Beach at 3.54km^2 (42.19%) and Bateau Bay at 3.08km^2 (35.42%); and Rocky Point and Hardy's Bay contained the smallest area of cover at 0.06km^2 (equivalent to 35.68% and 8.85%, respectively).

Canopy cover ranged from 7.03% (0.09 km^2) in Booker Bay to 89.58% in Ourimbah. Given the large proportion of forested areas and the large size of the suburb, Ourimbah also had the greatest area canopy cover at 93.96 km^2. The influence of this large forested area is highlighted when considering the next greatest area of canopy cover was 20 km^2 in Kariong, representing 64.84% of that suburb area, followed by 14.21km^2 in Patonga (39.58%). Comparatively, Rocky Point had the smallest area of cover at 0.04 km^2 (24.22%), followed by Blue Bay and Booker Bay at 0.06km^2 and 0.09km^2 (respectively 8.85% and 7.03%).

Plantable space ranged from 4.17% (0.18 km^2) in Koolewong to 42.19% (2.67km^2) in Woongarrah. By way of physical area though, Ourimbah presents the greatest opportunity for increasing canopy cover, with 6.83 km^2 of plantable space (6.51%), followed by 6.51km^2 in Kariong (21.09%). The least opportunity for increasing canopy cover appears to be in Rocky Point, Wagstaffe, Horsfield Bay and Phegans Bay, all of which had less than 0.1km^2 of potential plantable area (30.73%, 7.29%, 14.84%, and 10.94%, respectively). These areas of potential plantable space are particularly important strategically increasing canopy cover. When combined with thermal heat mapping, areas of plantable space that overlap with thermal hotspots can indicate priority planting locations. However, further assessments should first consider the tenure of land cover within suburbs, as Ourimbah may not have the greatest amount of plantable space on public land, which is where Council can have the most immediate impact.

The level of planting opportunities on private versus public land will need to be carefully considered, as to how representative such plantable space opportunities are for Council action.

Unplantable cover ranged from 0.52% (0.01km^2) in Wyongah to 67.45% (2.83km^2) in Koolewong. Koolewong's high percent unplantable cover was due primarily to the large proportion of Brisbane Water surface comprising this suburb (66.41%). The influence of water on thermal mapping outputs may be of particular interest as a potential cooling mechanism to support tree canopy cooling effects. The greatest area of unplantable space was 18.5km^2 (51.56%) in Patonga, again primarily due to this suburb comprising a large proportion of water surface, namely Broken Bay and the mouth of the Hawkesbury River. The lowest amount of unplantable area was in Wyongah and Rocky Point which both has 0.01km^2 worth.

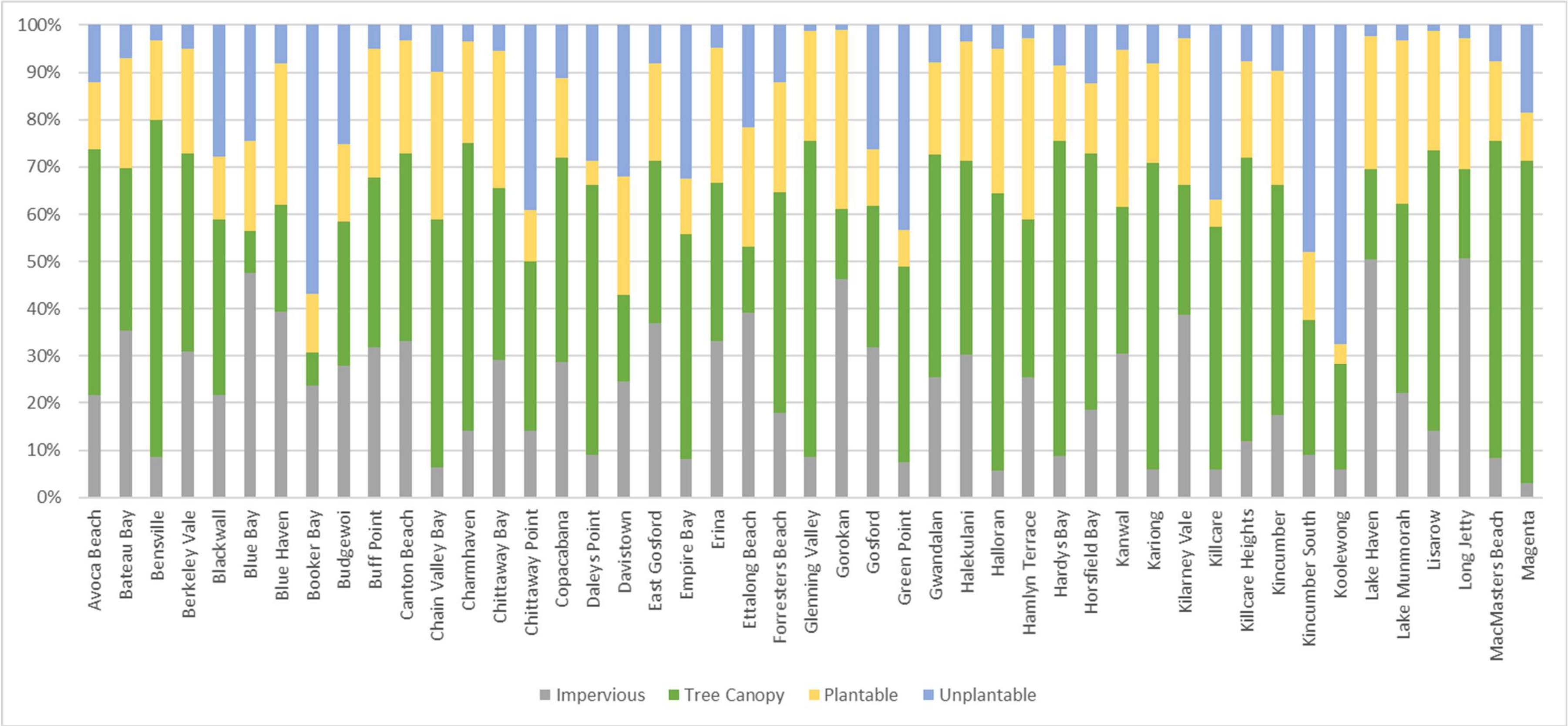


Figure 17. Percent current land cover for suburbs 1-47, ordered alphabetically. Refer to Appendix A for further details on percentages and equivalent land areas for each suburb.

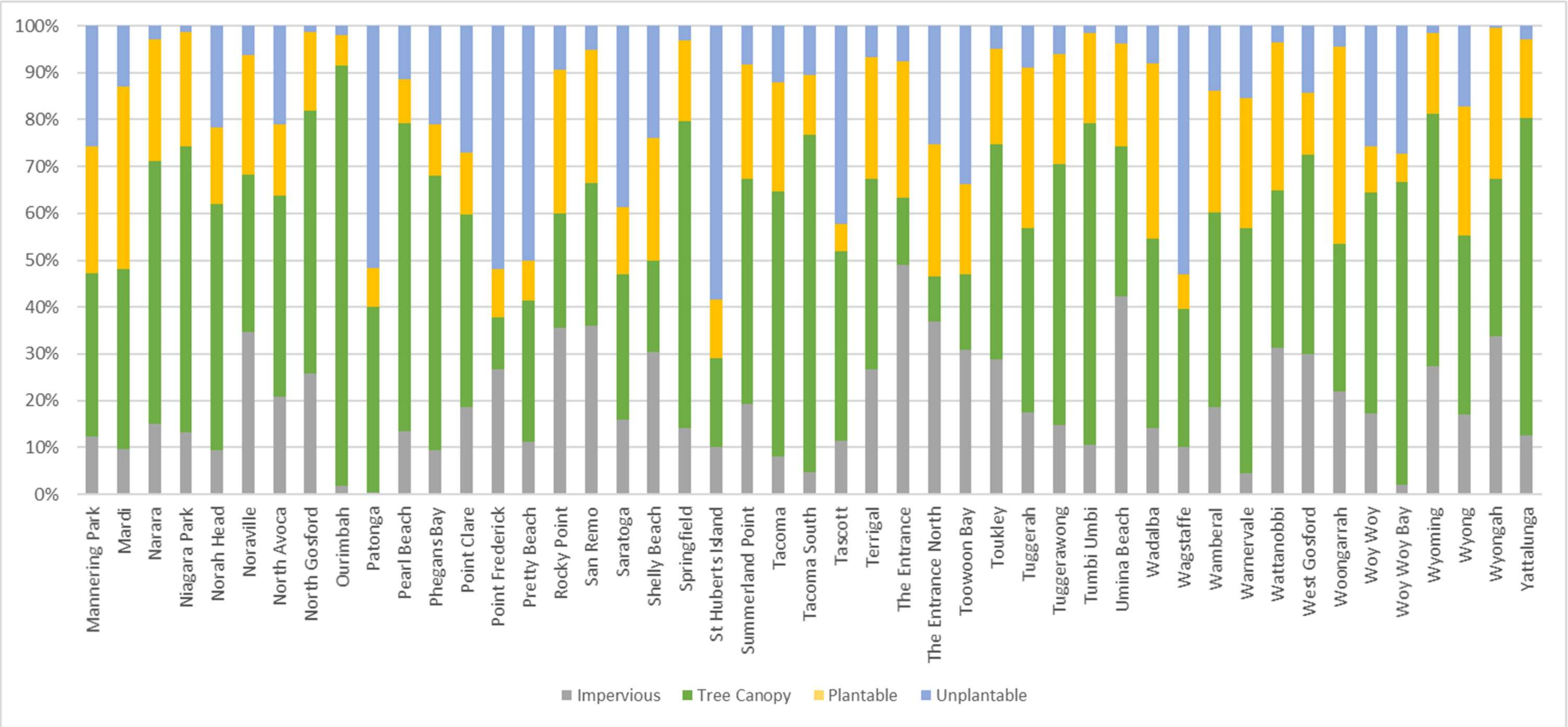


Figure 18. Percent current land cover for suburbs 48-94, ordered alphabetically. Refer to Appendix A for further details on percentages and equivalent land areas for each suburb.

3.3 Case study results – land cover change in Woy Woy

Over the nine years between 2005 and 2014, Woy Woy experienced changes in all land cover types, though the direction and statistical significance varied for each land cover type. Both impervious and unplantable space cover increased over time, though neither increase was statistically significant (Figure 19). Unplantable space cover increased by more than impervious cover (4.95%, 1.1 km^2 and 3.65%, 0.8 km^{2,} respectively), with an increase in unplantable bare ground being the primary driver (2.34%, 0.5 km^2). For impervious cover, other impervious surfaces increased the most, followed by buildings and then roads (2.08%, 0.47 km^2, 1.04%, 0.24 km^2, and 0.52%, 0.12 km^{2,} respectively). Over the same time, plantable space and tree canopy cover both decreased, by 7.55% (1.72km^2) and 1.04%, (0.24km^2) respectively (Figure 19). The loss of tree canopy cover was the only significant change for the suburb ($p = 0.037$). The total area lost was 1.73km^2, which is equivalent to just over 254 rugby league fields worth.

Trends of decreasing tree canopy and plantable space, together with increasing imperious and unplantable space are indictive of urban in-fill (Plate 2); a trend commonly observed in cities worldwide. Investigate of land cover change trends on private versus public land will further inform strategic decision-making and action prioritization. The increase in predominantly impervious bare ground includes current earthworks and building sites, indicating that in the future the amount of unplantable bare ground may decrease and impervious may increase as development occurs and buildings are built (Plates 2 and 3). For example, a conversion of 75% or more of the current unplantable bare ground to impervious would make the change in impervious cover since 2005 statistically significant. The trend appears to have continued since 2014 based on cursory interrogation of 2017 imagery for Woy Woy (Plate 3). If permitted to proceed unchecked, this pattern of land cover change, particularly the significant tree canopy loss, has substantial implications for the future liveabilty of cities and the health and well-being of urban environments and communities.

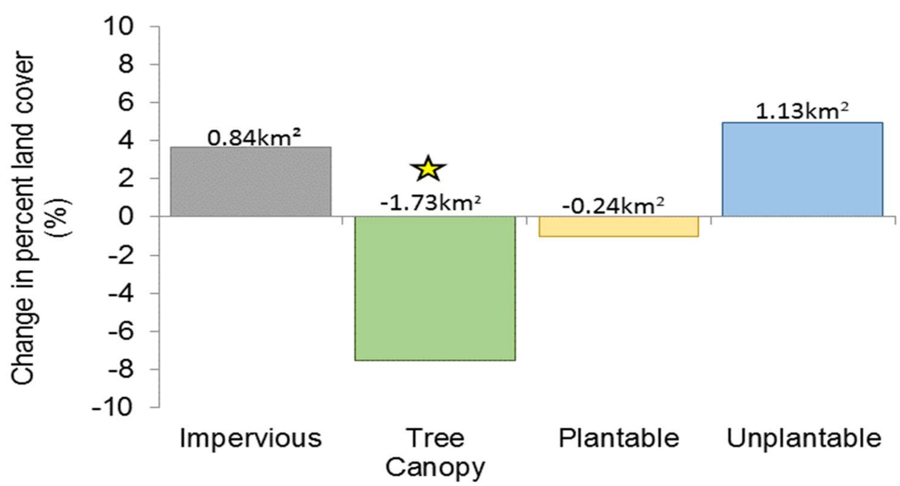


Figure 19. Change in impervious, tree canopy, plantable space and unplantable space cover in Woy Woy between 2005 and 2014. The equivalent amount land area is also shown for each land cover type, with a yellow star indicate a statistically significant change.

Plate 2. Aerial images showing examples of land cover change in Woy Woy between 2005 and 2017. The process of urban in-fill is clear, with trees and grassy areas replaced by impervious surfaces. Key changes between 2005 and 2014 are outlined in red on both images; additional urban in-fill and/or canopy loss between 2014 and 2017 are outlined in yellow on the 2014 image.

Plate 3. Aerial images showing example of urban in-fill in Woy Woy, and the conversion of tree canopy to unplantable bare ground to impervious. This highlights this importance of analysing land cover over time to fully appreciate trends in land cover change.

4 Key Findings

Thermal and urban tree canopy mapping of the Central Coast Council reveals substantial insights into the broad trends and relationships between land use, vegetation, and thermal performance. The suburb-level analysis allows for targeting of areas that exhibit the highest temperatures, highest and lowest vegetation, and the greatest chance for planting new trees. The time series assessment for thermal performance identifies which areas may increasingly become problems in the future. More detailed analysis of the data identifies specific areas where changes in land use have resulted in changes in thermal performance.

Key findings include the following:

- some suburbs were consistently hot in the time periods assessed, such as Long Jetty, Lake Haven, and Umina Beach. In contrast, others were hot initially and increased in heat over time including Ettalong Beach, Booker Bay, Point Frederick, Watanobbi, and Woongarrah;

- suburbs such as East Gosford and Blue Haven are emerging future heat centers;

- the most dominant heat island signal comes from Long Jetty with over 90% of its area falling within a heat island;

- across the 94 urban suburbs tree canopy was the dominant land cover type, covering nearly 42% (264km^2) of the urban area. Canopy cover within each suburb varied significantly, ranging from 7.03% (0.09km^2) in Booker Bay to 89.58% (93.96km^2) in Ourimbah;

- the percent cover of plantable space across all urban suburbs was about 21% (131km^2). Almost all of the plantable space are currently grassy areas rather than bare ground (18.62%,117 km^2 and 2.25%, 14.1 km^2, respectively). Plantable space ranged from 4.17% (0.18 km^2) in Koolewong to 42.19% (2.67km^2) in Woongarrah. The greatest areas of plantable space however occur in Ourimbah (6.51%, 6.83km^2) and Kariong (21.09%, 6.51km^2);

- an understanding of land cover by tenure within each suburb will greatly enhance strategic decision-making, particularly the amount of plantable space on public versus private land;

- the Woy Woy case study shows the power of investigating land cover change over time to gain a greater understanding of specific drivers of change. This could further be refined by integrating tenure analyses, to understand drivers of change on public and private land;

- the target suburbs analysed as part of the heat island analysis indicated that development is leading to warmer suburbs and that cooling is associated with more green infrastructure.

Specific locations can be identified for heat mitigation activities by identifying areas with the largest numbers of people that may be exposed and/or are vulnerable to excessive urban heat. A priority neighbourhoods framework was developed by Norton, et al. (2015), which identifies areas of heat exposure, behavioural exposure and social vulnerability, and where they intersect, to determine the location of priority areas for mitigation actions (Figure 20).

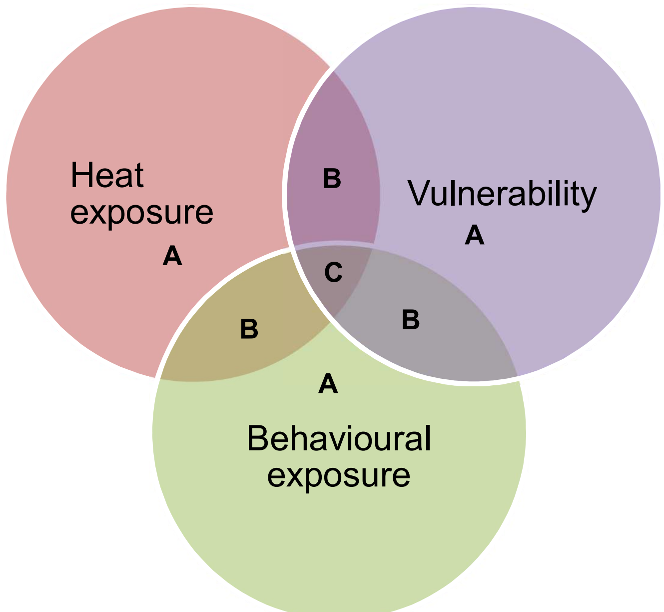


Figure 20. Framework to identify priority neighbourhoods for heat mitigation activities. Factors required to identify neighbourhoods of high (C), medium (B) and moderate (A) priority for urban green infrastructure (UGI) implementation for surface temperature heat mitigation. The key factors are high daytime surface temperatures (heat exposure) intersecting with areas with more vulnerable sections of society (vulnerability) and identifying the zones of high activity (behavioural exposure) in this area (Norton, et al., 2015).

Combining the suburb level thermal assessment with the i-Tree vegetation assessment reveals areas where high temperatures and plantable spaces align. These suburbs represent opportunities for capitalizing on the cooling benefits of green infrastructure.

To understand where high temperatures were close to plantable opportunities, suburbs were ranked from hottest to coolest, and from highest percent of plantable space to lowest (Table 9). These rankings were combined to provide a “hot and plantable” ranking showing which suburbs would benefit most from additional green infrastructure. The results of this analysis suggest that suburbs such as Woongarrah, Hamlyn Terrace, Blue Haven, Gorokan and Wadalba are the highest priority for planting because of the higher than regional average surface temperatures and the availability of open space. Of the target suburbs identified by Council, three are in the top 12 ranked suburbs (Lake Haven, Erina, The Entrance).

Table 9. Ranking of suburbs in the Central Coast Council based on relative average surface temperature above that of the region, and the availability of open space for the planting. Suburbs in bold text are those identified as priorities by Central Coast Council.

Rank	Suburbs with combined heat and plantable space	Relative Temperature (°C)	Plantable Space (%)
1st	WOONGARRAH	+ 4.07	42.19
2nd	HAMLYN TERRACE	+ 3.37	38.28
3rd	BLUE HAVEN	+ 4.00	29.95
4th	GOROKAN	+ 2.93	37.76
5th	WADALBA	+ 2.84	37.24
6th	KANWAL	+ 3.05	33.33
7th	**LAKE HAVEN**	+ 3.88	28.13
8th	LONG JETTY	+ 3.41	27.60
9th	ETTALONG BEACH	+ 5.73	25.26
10th	SAN REMO	+ 3.13	28.39
11th	**ERINA**	+ 3.05	28.65
12th	**THE ENTRANCE**	+ 2.50	29.17
...	...	...	...
22nd	**WYONG**	+ 1.70	27.60
25th	**TERRIGAL**	+ 1.66	25.78
32nd	**TUGGERAH**	+ 0.53	34.38
33rd	**WARNERVALE**	+ 0.87	27.86
39th	**GOSFORD**	+ 3.21	11.98
55th	**KARIONG**	+ 0.74	21.09
58th	**WOY WOY**	+ 1.74	9.90
71st	**TOUKLEY**	-0.76	20.31

The determination of actual plantable space needs to be supplemented with an onground assessment of factors such as the width of verges, location of power lines and presence of underground services, all of which influence whether a tree can be planted, and grow to maturity, in a given location. Once the right tree is chosen for the right place, other factors will also influence the successful establishment of trees, such as water availability, soil type (e.g. sandy soils can lead to lower establishment rates) and seasonal conditions. An analysis of onground planting factors should complement any further prioritising of areas to plant trees to mitigate heat islands.

The planting priority analysis could be further added to by understanding the alignment of these areas with the distribution of vulnerable people and behavioural exposure (e.g. outdoors lawn bowls clubs, bikeways, footpaths and playgrounds). Further refinement to inform decision-making could come from analysis of land cover by tenure, which would enable, for example, areas of plantable space opportunities on public land (where Council can most readily act) to be differentiated from areas of plantable space on private land (which would require community and private land holder contribution).

Other than the presence of trees, other land use management decisions can be made that influence the temperature in cities. For example, dark coloured, impervious surfaces such as bitumen roads and dark roofs can absorb large amounts of heat while artificial turf, rubber soft fall matting used in playgrounds, and bare ground can also be amongst the hottest land surface types in an urban landscape (e.g. City of West Torrens, 2017). Importantly for the urban heat island effect, bitumen roads retain this heat into the evening and re-radiate heat well into the night. In contrast, green space features like living turf are cooler than average during the day and night. For example, urban heat island analysis in Adelaide found that there was a 14°C different in the surface temperature of artificial compared with living turf on a warm summer day.

Actions to mitigate the urban heat island need to be well costed. As such, consideration should be given as to whether it is more cost effective to choose materials and make land use decisions at the development stage to create a cooler city, or whether retrofitting can achieve the same outcomes after development and building construction has occurred. In the case of the latter, smaller block sizes can mean that land use features that lead to cooling, such as open green space, are more challenging to install after development has occurred.

This analysis and the data created provide a high-level assessment of the current land cover baselines for each urban suburb and locations where heat change has occurred. Further investigation of this data, such as looking at large developments that have taken place between 2013-2018, tenure analyses, and land cover change over time will further reveal the impact that development and planting programs have on the thermal performance of the Central Coast Council landscape.

References

Al-doski, J., Mansor, S.B. and Shafri, H.Z.M., 2013. NDVI differencing and post classification to detect vegetation changes in Halabja city, Iraq. IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG), 1(2), pp.01-10.

BOM, 2018. Gosford, New South Wales January 2018 Daily Weather Observations. Australian Bureau of Meteorology. <http://www.bom.gov.au/climate/dwo/201801/html/IDCJDW2048.201801.shtml>

Central Coast Community Strategic Plan 2018-2028. Central Coast Council <https://www.yourvoiceourcoast.com/help-shape-the-future-of-the-coast>

City of West Torrens, 2017. *Western Adelaide Urban Heat Mapping Report.* Prepared by Seed Consulting Services, EnDev Geographic and Airborne Research Australia.

Jacobs, B; Mikhailovich, N; Delaney, C (2014) *Benchmarking Australia's Urban Tree Canopy: An i-Tree Assessment.* Report prepared for Horticulture Australia Limited by the Institute for Sustainable Futures, NSW.

Landsat 8 User's Manual, 2016. Landsat 8 Data Users Handbook, version 2.0. Department of the Interior U.S. Geological Survey. March 29, 2016

Martin, P., Baudouin, Y. and Gachon, P., 2015. An alternative method to characterize the surface urban heat island. International journal of biometeorology, 59(7), pp.849-861.

Norton, B. A., Coutts, A. M., Livesley, S. J., Harris, R. J., Hunter, A. M., Williams, N. S., 2015. Planning for cooler cities: A framework to prioritise green infrastructure to mitigate high temperatures in urban landscapes. *Landscape and Urban Planning,* Volume 134, pp. 127-138.

Faidvs09fhb9

Appendix A. Land Cover for Each Urban Suburb

The following Table shows, for each urban suburb assessed, the area (km^2) of the suburb (includes water bodies) and the outputs for each land cover type. Land cover types are as follows:

- Impervious cover = impervious – building (IB), impervious – other (IO), and impervious – road (IR);
- Tree canopy cover = tree over pervious surface (TP), and tree over impervious surface (TI);
- Plantable space cover = bare ground (PBG), and grass (PGr);
- Unplantable space cover = agriculture (UAg), aquatic vegetation (UAV), bare ground (UBG), grass (UGr), sand (USa), and water (UWa).

Outputs presented for each land cover type are:

- Pts = Number of i-Tree Canopy points classified as that land cover type (out of 384);
- % Sub = equivalent percent cover across the suburb for that land cover type; and
- Area km^2 = equivalent area in square kilometres of that land cover type.

Suburb	Area km2	IB Pts	IB % Sub	IB Area km2	IO Pts	IO % Sub	IO Area km2	IR Pts	IR % Sub	IR Area km2	TP Pts	TP % Sub	TP Area km2	TI Pts	TI % Sub	TI Area km2	PBG Pts	PBG % Sub	PBG Area km2	PGr Pts	PGr % Sub	PGr Area km2
Avoca Beach	5.20	40	10.42	0.54	26	6.77	0.35	17	4.43	0.23	174	45.31	2.35	26	6.77	0.35	8	2.08	0.11	47	12.24	0.64
Bateau Bay	8.70	57	14.84	1.29	36	9.38	0.82	43	11.20	0.97	113	29.43	2.56	19	4.95	0.43	4	1.04	0.09	85	22.14	1.93
Bensville	6.67	15	3.91	0.26	5	1.30	0.09	13	3.39	0.23	266	69.27	4.62	8	2.08	0.14	8	2.08	0.14	57	14.84	0.99
Berkeley Vale	7.33	57	14.84	1.09	34	8.85	0.65	28	7.29	0.53	144	37.50	2.75	17	4.43	0.32	5	1.30	0.10	80	20.83	1.53
Blackwall	1.92	44	11.46	0.22	22	5.73	0.11	17	4.43	0.09	133	34.64	0.67	10	2.60	0.05	18	4.69	0.09	33	8.59	0.17
Blue Bay	0.64	87	22.66	0.15	58	15.10	0.10	38	9.90	0.06	26	6.77	0.04	8	2.08	0.01	3	0.78	0.01	70	18.23	0.12
Blue Haven	3.06	89	23.18	0.71	38	9.90	0.30	24	6.25	0.19	72	18.75	0.57	15	3.91	0.12	7	1.82	0.06	108	28.13	0.86
Booker Bay	1.23	47	12.24	0.15	33	8.59	0.11	11	2.86	0.04	23	5.99	0.07	4	1.04	0.01	6	1.56	0.02	42	10.94	0.13
Budgewoi	3.73	36	9.38	0.35	37	9.64	0.36	34	8.85	0.33	100	26.04	0.97	17	4.43	0.17	7	1.82	0.07	56	14.58	0.54
Buff Point	2.46	69	17.97	0.44	20	5.21	0.13	33	8.59	0.21	128	33.33	0.82	10	2.60	0.06	7	1.82	0.04	98	25.52	0.63
Canton Beach	1.02	60	15.63	0.16	31	8.07	0.08	36	9.38	0.10	138	35.94	0.37	15	3.91	0.04	6	1.56	0.02	86	22.40	0.23
Chain Valley Bay	7.10	9	2.34	0.17	5	1.30	0.09	10	2.60	0.18	194	50.52	3.59	8	2.08	0.15	7	1.82	0.13	113	29.43	2.09
Charmhaven	8.35	26	6.77	0.57	14	3.65	0.30	14	3.65	0.30	227	59.11	4.94	7	1.82	0.15	6	1.56	0.13	77	20.05	1.67
Chittaway Bay	1.31	51	13.28	0.17	35	9.11	0.12	26	6.77	0.09	127	33.07	0.43	13	3.39	0.04	4	1.04	0.01	107	27.86	0.37
Chittaway Point	1.88	28	7.29	0.14	18	4.69	0.09	8	2.08	0.04	121	31.51	0.59	17	4.43	0.08	5	1.30	0.02	37	9.64	0.18
Copacabana	2.48	51	13.28	0.33	34	8.85	0.22	25	6.51	0.16	146	38.02	0.94	20	5.21	0.13	8	2.08	0.05	57	14.84	0.37
Daleys Point	2.25	16	4.17	0.09	15	3.91	0.09	4	1.04	0.02	208	54.17	1.22	11	2.86	0.06	4	1.04	0.02	16	4.17	0.09
Davistown	2.82	40	10.42	0.29	36	9.38	0.26	18	4.69	0.13	64	16.67	0.47	7	1.82	0.05	26	6.77	0.19	70	18.23	0.51
East Gosford	2.44	66	17.19	0.42	45	11.72	0.29	31	8.07	0.20	118	30.73	0.75	14	3.65	0.09	3	0.78	0.02	76	19.79	0.48
Empire Bay	6.77	15	3.91	0.26	8	2.08	0.14	8	2.08	0.14	175	45.57	3.08	8	2.08	0.14	4	1.04	0.07	41	10.68	0.72
Erina	6.21	60	15.63	0.97	47	12.24	0.76	20	5.21	0.32	119	30.99	1.92	10	2.60	0.16	10	2.60	0.16	100	26.04	1.62
Ettalong Beach	2.55	80	20.83	0.53	35	9.11	0.23	35	9.11	0.23	40	10.42	0.27	14	3.65	0.09	22	5.73	0.15	75	19.53	0.50
Forresters Beach	3.39	24	6.25	0.21	31	8.07	0.27	14	3.65	0.12	169	44.01	1.49	10	2.60	0.09	10	2.60	0.09	80	20.83	0.71
Glenning Valley	6.79	16	4.17	0.28	7	1.82	0.12	10	2.60	0.18	250	65.10	4.42	7	1.82	0.12	6	1.56	0.11	83	21.61	1.47
Gorokan	3.63	80	20.83	0.76	55	14.32	0.52	43	11.20	0.41	46	11.98	0.44	11	2.86	0.10	3	0.78	0.03	142	36.98	1.34
Gosford	4.10	47	12.24	0.50	41	10.68	0.44	34	8.85	0.36	106	27.60	1.13	9	2.34	0.10	17	4.43	0.18	29	7.55	0.31
Green Point	18.27	12	3.13	0.57	10	2.60	0.48	7	1.82	0.33	148	38.54	7.04	11	2.86	0.52	5	1.30	0.24	25	6.51	1.19
Gwandalan	3.77	43	11.20	0.42	26	6.77	0.26	29	7.55	0.28	168	43.75	1.65	13	3.39	0.13	16	4.17	0.16	59	15.36	0.58
Halekulani	1.75	66	17.19	0.30	26	6.77	0.12	24	6.25	0.11	135	35.16	0.62	23	5.99	0.11	9	2.34	0.04	88	22.92	0.40
Halloran	3.49	4	1.04	0.04	6	1.56	0.05	12	3.13	0.11	223	58.07	2.03	2	0.52	0.02	8	2.08	0.07	110	28.65	1.00
Hamlyn Terrace	6.27	43	11.20	0.70	23	5.99	0.38	32	8.33	0.52	118	30.73	1.93	10	2.60	0.16	4	1.04	0.07	143	37.24	2.33
Hardys Bay	0.71	17	4.43	0.03	7	1.82	0.01	10	2.60	0.02	209	54.43	0.39	47	12.24	0.09	14	3.65	0.03	47	12.24	0.09
Horsfield Bay	0.54	33	8.59	0.05	20	5.21	0.03	18	4.69	0.03	177	46.09	0.25	32	8.33	0.04	12	3.13	0.02	45	11.72	0.06
Kanwal	3.03	50	13.02	0.39	42	10.94	0.33	25	6.51	0.20	98	25.52	0.77	21	5.47	0.17	8	2.08	0.06	120	31.25	0.95
Kariong	30.84	7	1.82	0.56	11	2.86	0.88	5	1.30	0.40	229	59.64	18.39	20	5.21	1.61	6	1.56	0.48	75	19.53	6.02
Kilarney Vale	3.64	67	17.45	0.63	38	9.90	0.38	44	11.46	0.42	88	22.92	0.83	17	4.43	0.16	5	1.30	0.05	114	29.69	1.08
Killcare	2.98	14	3.65	0.11	5	1.30	0.04	4	1.04	0.03	189	49.22	1.47	8	2.08	0.06	2	0.52	0.02	20	5.21	0.16
Killcare Heights	2.62	22	5.73	0.15	9	2.34	0.06	15	3.91	0.10	205	53.39	1.40	25	6.51	0.17	9	2.34	0.06	70	18.23	0.48
Kincumber	12.33	25	6.51	0.80	21	5.47	0.67	21	5.47	0.67	176	45.83	5.65	11	2.86	0.35	6	1.56	0.19	87	22.66	2.79
Kincumber South	2.76	18	4.69	0.13	8	2.08	0.06	9	2.34	0.06	101	26.30	0.73	8	2.08	0.06	9	2.34	0.06	47	12.24	0.34
Koolewong	4.20	12	3.13	0.13	6	1.56	0.07	5	1.30	0.05	82	21.35	0.90	4	1.04	0.04	1	0.26	0.01	15	3.91	0.16
Lake Haven	2.07	88	22.92	0.48	66	17.19	0.36	40	10.42	0.22	61	15.89	0.33	12	3.13	0.06	5	1.30	0.03	103	26.82	0.56
Lake Munmorah	6.65	43	11.20	0.74	23	5.99	0.40	19	4.95	0.33	142	36.98	2.46	12	3.13	0.21	10	2.60	0.17	123	32.03	2.13
Lisarow	13.03	17	4.43	0.58	22	5.73	0.75	15	3.91	0.51	220	57.29	7.46	8	2.08	0.27	6	1.56	0.20	91	23.70	3.09
Long Jetty	3.05	91	23.70	0.72	57	14.84	0.45	47	12.24	0.37	57	14.84	0.45	15	3.91	0.12	5	1.30	0.04	101	26.30	0.80

Suburb	UAg Pts	UAg % Sub	UAg Area km2	UAV Pts	UAV % Sub	UAV Area km2	UBG Pts	UBG % Sub	UBG Area km2	UGr Pts	UGr % Sub	UGr Area km2	USa Pts	USa % Sub	USa Area km2	UWa Pts	UWa % Sub	UWa Area km2
Avoca Beach	0	0.00	0.00	0	0.00	0.00	6	1.56	0.08	4	1.04	0.05	5	1.30	0.07	31	8.07	0.42
Bateau Bay	0	0.00	0.00	2	0.52	0.05	11	2.86	0.25	12	3.13	0.27	2	0.52	0.05	0	0.00	0.00
Bensville	0	0.00	0.00	7	1.82	0.12	2	0.52	0.03	0	0.00	0.00	3	0.78	0.05	0	0.00	0.00
Berkeley Vale	0	0.00	0.00	1	0.26	0.02	14	3.65	0.27	3	0.78	0.06	0	0.00	0.00	1	0.26	0.02
Blackwall	0	0.00	0.00	0	0.00	0.00	1	0.26	0.01	0	0.00	0.00	0	0.00	0.00	106	27.60	0.53
Blue Bay	0	0.00	0.00	4	1.04	0.01	46	11.98	0.08	0	0.00	0.00	21	5.47	0.04	23	5.99	0.04
Blue Haven	0	0.00	0.00	12	3.13	0.10	3	0.78	0.02	3	0.78	0.02	0	0.00	0.00	13	3.39	0.10
Booker Bay	0	0.00	0.00	0	0.00	0.00	3	0.78	0.01	1	0.26	0.00	3	0.78	0.01	211	54.95	0.68
Budgewoi	0	0.00	0.00	29	7.55	0.28	2	0.52	0.02	15	3.91	0.15	25	6.51	0.24	26	6.77	0.25
Buff Point	0	0.00	0.00	0	0.00	0.00	2	0.52	0.01	9	2.34	0.06	0	0.00	0.00	8	2.08	0.05
Canton Beach	0	0.00	0.00	4	1.04	0.01	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	8	2.08	0.02
Chain Valley Bay	0	0.00	0.00	20	5.21	0.37	4	1.04	0.07	1	0.26	0.02	0	0.00	0.00	13	3.39	0.24
Charmhaven	0	0.00	0.00	3	0.78	0.07	3	0.78	0.07	1	0.26	0.02	0	0.00	0.00	6	1.56	0.13
Chittaway Bay	0	0.00	0.00	5	1.30	0.02	3	0.78	0.01	6	1.56	0.02	0	0.00	0.00	7	1.82	0.02
Chittaway Point	0	0.00	0.00	87	22.66	0.43	0	0.00	0.00	1	0.26	0.00	0	0.00	0.00	62	16.15	0.30
Copacabana	0	0.00	0.00	7	1.82	0.05	16	4.17	0.10	0	0.00	0.00	4	1.04	0.03	16	4.17	0.10
Daleys Point	0	0.00	0.00	0	0.00	0.00	4	1.04	0.02	0	0.00	0.00	1	0.26	0.01	105	27.34	0.62
Davistown	0	0.00	0.00	7	1.82	0.05	4	1.04	0.03	2	0.52	0.01	1	0.26	0.01	109	28.39	0.80
East Gosford	0	0.00	0.00	1	0.26	0.01	4	1.04	0.03	21	5.47	0.13	0	0.00	0.00	5	1.30	0.03
Empire Bay	0	0.00	0.00	4	1.04	0.07	12	3.13	0.21	3	0.78	0.05	0	0.00	0.00	106	27.60	1.87
Erina	0	0.00	0.00	0	0.00	0.00	9	2.34	0.15	1	0.26	0.02	0	0.00	0.00	8	2.08	0.13
Ettalong Beach	0	0.00	0.00	2	0.52	0.01	5	1.30	0.03	1	0.26	0.01	6	1.56	0.04	69	17.97	0.46
Forresters Beach	0	0.00	0.00	0	0.00	0.00	27	7.03	0.24	3	0.78	0.03	8	2.08	0.07	8	2.08	0.07
Glenning Valley	0	0.00	0.00	1	0.26	0.02	2	0.52	0.04	2	0.52	0.04	0	0.00	0.00	0	0.00	0.00
Gorokan	0	0.00	0.00	0	0.00	0.00	1	0.26	0.01	3	0.78	0.03	0	0.00	0.00	0	0.00	0.00
Gosford	0	0.00	0.00	0	0.00	0.00	9	2.34	0.10	29	7.55	0.31	0	0.00	0.00	63	16.41	0.67
Green Point	0	0.00	0.00	0	0.00	0.00	6	1.56	0.29	0	0.00	0.00	0	0.00	0.00	160	41.67	7.61
Gwandalan	0	0.00	0.00	2	0.52	0.02	9	2.34	0.09	0	0.00	0.00	0	0.00	0.00	19	4.95	0.19
Halekulani	0	0.00	0.00	0	0.00	0.00	10	2.60	0.05	1	0.26	0.00	0	0.00	0.00	2	0.52	0.01
Halloran	0	0.00	0.00	2	0.52	0.02	7	1.82	0.06	1	0.26	0.01	0	0.00	0.00	9	2.34	0.08
Hamlyn Terrace	0	0.00	0.00	2	0.52	0.03	7	1.82	0.11	1	0.26	0.02	0	0.00	0.00	1	0.26	0.02
Hardys Bay	0	0.00	0.00	1	0.26	0.00	21	5.47	0.04	11	2.86	0.02	0	0.00	0.00	0	0.00	0.00
Horsfield Bay	0	0.00	0.00	0	0.00	0.00	5	1.30	0.01	1	0.26	0.00	0	0.00	0.00	41	10.68	0.06
Kanwal	0	0.00	0.00	1	0.26	0.01	2	0.52	0.02	13	3.39	0.10	0	0.00	0.00	4	1.04	0.03
Kariong	0	0.00	0.00	1	0.26	0.08	17	4.43	1.37	12	3.13	0.96	0	0.00	0.00	1	0.26	0.08
Kilarney Vale	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	9	2.34	0.09	0	0.00	0.00	2	0.52	0.02
Killcare	0	0.00	0.00	6	1.56	0.05	2	0.52	0.02	0	0.00	0.00	11	2.86	0.09	123	32.03	0.95
Killcare Heights	0	0.00	0.00	2	0.52	0.01	10	2.60	0.07	2	0.52	0.01	7	1.82	0.05	8	2.08	0.05
Kincumber	0	0.00	0.00	0	0.00	0.00	7	1.82	0.22	2	0.52	0.06	0	0.00	0.00	28	7.29	0.90
Kincumber South	0	0.00	0.00	4	1.04	0.03	0	0.00	0.00	5	1.30	0.04	0	0.00	0.00	175	45.57	1.26
Koolewong	0	0.00	0.00	0	0.00	0.00	3	0.78	0.03	1	0.26	0.01	0	0.00	0.00	255	66.41	2.79
Lake Haven	0	0.00	0.00	0	0.00	0.00	2	0.52	0.01	7	1.82	0.04	0	0.00	0.00	0	0.00	0.00
Lake Munmorah	2	0.52	0.03	1	0.26	0.02	3	0.78	0.05	3	0.78	0.05	0	0.00	0.00	3	0.78	0.05
Lisarow	0	0.00	0.00	0	0.00	0.00	4	1.04	0.14	1	0.26	0.03	0	0.00	0.00	0	0.00	0.00
Long Jetty	0	0.00	0.00	2	0.52	0.02	5	1.30	0.04	4	1.04	0.03	0	0.00	0.00	0	0.00	0.00

		IB			IO			IR			TP			TI			PBG			PGr			UAg			UAV			UBG			UGr			USa			UWa		
Suburb	Area km2	Pts	% Sub	Area km2	Pts	% Sub	Area km2	Pts	% Sub	Area km2	Pts	% Sub	Area km2	Pts	% Sub	Area km2	Pts	% Sub	Area km2	Pts	% Sub	Area km2	Pts	% Sub	Area km2	Pts	% Sub	Area km2	Pts	% Sub	Area km2	Pts	% Sub	Area km2	Pts	% Sub	Area km2	Pts	% Sub	Area km2
MacMasters Beach	6.51	15	3.91	0.25	9	2.34	0.15	8	2.08	0.14	248	64.58	4.21	10	2.60	0.17	10	2.60	0.17	55	14.32	0.93	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	1	0.26	0.02	0	0.00	0.00	28	7.29	0.47
Magenta	8.36	2	0.52	0.04	5	1.30	0.11	5	1.30	0.11	259	67.45	5.64	3	0.78	0.07	14	3.65	0.30	25	6.51	0.54	0	0.00	0.00	19	4.95	0.41	1	0.26	0.02	21	5.47	0.46	27	7.03	0.59	3	0.78	0.07
Mannering Park	8.89	18	4.69	0.42	20	5.21	0.46	9	2.34	0.21	129	33.59	2.99	5	1.30	0.12	31	8.07	0.72	73	19.01	1.69	0	0.00	0.00	10	2.60	0.23	63	16.41	1.46	2	0.52	0.05	0	0.00	0.00	24	6.25	0.56
Mardi	11.26	12	3.13	0.35	15	3.91	0.44	10	2.60	0.29	145	37.76	4.25	3	0.78	0.09	11	2.86	0.32	138	35.94	4.05	0	0.00	0.00	9	2.34	0.26	8	2.08	0.23	1	0.26	0.03	0	0.00	0.00	32	8.33	0.94
Narara	10.00	26	6.77	0.68	21	5.47	0.55	11	2.86	0.29	205	53.39	5.34	10	2.60	0.26	11	2.86	0.29	89	23.18	2.32	0	0.00	0.00	0	0.00	0.00	6	1.56	0.16	3	0.78	0.08	0	0.00	0.00	2	0.52	0.05
Niagara Park	4.52	28	7.29	0.33	10	2.60	0.12	13	3.39	0.15	226	58.85	2.66	8	2.08	0.09	5	1.30	0.06	89	23.18	1.05	0	0.00	0.00	1	0.26	0.01	3	0.78	0.04	1	0.26	0.01	0	0.00	0.00	0	0.00	0.00
Norah Head	4.63	12	3.13	0.14	12	3.13	0.14	12	3.13	0.14	198	51.56	2.39	4	1.04	0.05	8	2.08	0.10	55	14.32	0.66	0	0.00	0.00	15	3.91	0.18	29	7.55	0.35	5	1.30	0.06	24	6.25	0.29	10	2.60	0.12
Noraville	2.36	63	16.41	0.39	36	9.38	0.22	34	8.85	0.21	116	30.21	0.71	13	3.39	0.08	7	1.82	0.04	91	23.70	0.56	0	0.00	0.00	3	0.78	0.02	6	1.56	0.04	8	2.08	0.05	7	1.82	0.04	0	0.00	0.00
North Avoca	2.08	39	10.16	0.21	21	5.47	0.11	20	5.21	0.11	147	38.28	0.80	18	4.69	0.10	13	3.39	0.07	45	11.72	0.24	0	0.00	0.00	11	2.86	0.06	10	2.60	0.05	1	0.26	0.01	13	3.39	0.07	46	11.98	0.25
North Gosford	2.28	40	10.42	0.24	39	10.16	0.23	20	5.21	0.12	198	51.56	1.18	17	4.43	0.10	9	2.34	0.05	56	14.58	0.33	0	0.00	0.00	0	0.00	0.00	5	1.30	0.03	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
Ourimbah	104.89	2	0.52	0.55	3	0.78	0.82	2	0.52	0.55	342	89.06	93.42	2	0.52	0.55	4	1.04	1.09	21	5.47	5.74	0	0.00	0.00	1	0.26	0.27	6	1.56	1.64	1	0.26	0.27	0	0.00	0.00	0	0.00	0.00
Patonga	35.89	1	0.26	0.09	0	0.00	0.00	1	0.26	0.09	151	39.32	14.11	1	0.26	0.09	3	0.78	0.28	29	7.55	2.71	0	0.00	0.00	1	0.26	0.09	15	3.91	1.40	2	0.52	0.19	1	0.26	0.09	179	46.61	16.73
Pearl Beach	1.50	33	8.59	0.13	7	1.82	0.03	12	3.13	0.05	220	57.29	0.86	32	8.33	0.12	5	1.30	0.02	31	8.07	0.12	0	0.00	0.00	4	1.04	0.02	9	2.34	0.04	4	1.04	0.02	18	4.69	0.07	9	2.34	0.04
Phegans Bay	0.78	12	3.13	0.02	17	4.43	0.03	7	1.82	0.01	207	53.91	0.42	18	4.69	0.04	8	2.08	0.02	34	8.85	0.07	0	0.00	0.00	0	0.00	0.00	14	3.65	0.03	2	0.52	0.00	0	0.00	0.00	65	16.93	0.13
Point Clare	5.57	37	9.64	0.54	14	3.65	0.20	20	5.21	0.29	142	36.98	2.06	16	4.17	0.23	9	2.34	0.13	42	10.94	0.61	0	0.00	0.00	0	0.00	0.00	10	2.60	0.15	2	0.52	0.03	0	0.00	0.00	92	23.96	1.34
Point Frederick	1.42	46	11.98	0.17	40	10.42	0.15	16	4.17	0.06	28	7.29	0.10	15	3.91	0.06	5	1.30	0.02	35	9.11	0.13	0	0.00	0.00	1	0.26	0.00	2	0.52	0.01	0	0.00	0.00	0	0.00	0.00	196	51.04	0.73
Pretty Beach	1.13	17	4.43	0.05	12	3.13	0.04	14	3.65	0.04	101	26.30	0.30	15	3.91	0.04	3	0.78	0.01	30	7.81	0.09	0	0.00	0.00	0	0.00	0.00	9	2.34	0.03	4	1.04	0.01	0	0.00	0.00	179	46.61	0.53
Rocky Point	0.16	69	17.97	0.03	44	11.46	0.02	24	6.25	0.01	70	18.23	0.03	23	5.99	0.01	1	0.26	0.00	117	30.47	0.05	0	0.00	0.00	2	0.52	0.00	3	0.78	0.00	1	0.26	0.00	0	0.00	0.00	30	7.81	0.01
San Remo	2.74	67	17.45	0.48	33	8.59	0.24	38	9.90	0.27	98	25.52	0.70	19	4.95	0.14	6	1.56	0.04	103	26.82	0.74	0	0.00	0.00	0	0.00	0.00	6	1.56	0.04	7	1.82	0.05	0	0.00	0.00	7	1.82	0.05
Saratoga	4.69	29	7.55	0.35	20	5.21	0.24	12	3.13	0.15	105	27.34	1.28	14	3.65	0.17	9	2.34	0.11	46	11.98	0.56	0	0.00	0.00	0	0.00	0.00	1	0.26	0.01	2	0.52	0.02	0	0.00	0.00	146	38.02	1.78
Shelly Beach	1.42	58	15.10	0.21	31	8.07	0.11	28	7.29	0.10	68	17.71	0.25	7	1.82	0.03	5	1.30	0.02	95	24.74	0.35	0	0.00	0.00	17	4.43	0.06	4	1.04	0.01	45	11.72	0.17	26	6.77	0.10	0	0.00	0.00
Springfield	5.48	28	7.29	0.40	15	3.91	0.21	11	2.86	0.16	242	63.02	3.45	10	2.60	0.14	10	2.60	0.14	56	14.58	0.80	0	0.00	0.00	3	0.78	0.04	1	0.26	0.01	4	1.04	0.06	0	0.00	0.00	4	1.04	0.06
St Huberts Island	3.26	20	5.21	0.17	15	3.91	0.13	4	1.04	0.03	62	16.15	0.53	11	2.86	0.09	11	2.86	0.09	37	9.64	0.31	0	0.00	0.00	5	1.30	0.04	1	0.26	0.01	0	0.00	0.00	1	0.26	0.01	217	56.51	1.84
Summerland Point	3.78	37	9.64	0.36	20	5.21	0.20	17	4.43	0.17	176	45.83	1.73	9	2.34	0.09	24	6.25	0.24	69	17.97	0.68	0	0.00	0.00	0	0.00	0.00	4	1.04	0.04	0	0.00	0.00	0	0.00	0.00	28	7.29	0.28
Tacoma	2.81	15	3.91	0.11	6	1.56	0.04	10	2.60	0.07	213	55.47	1.56	4	1.04	0.03	4	1.04	0.03	86	22.40	0.63	0	0.00	0.00	12	3.13	0.09	0	0.00	0.00	5	1.30	0.04	0	0.00	0.00	29	7.55	0.21
Tacoma South	1.61	8	2.08	0.03	6	1.56	0.03	4	1.04	0.02	273	71.09	1.15	4	1.04	0.02	4	1.04	0.02	45	11.72	0.19	0	0.00	0.00	3	0.78	0.01	0	0.00	0.00	1	0.26	0.00	0	0.00	0.00	36	9.38	0.15
Tascott	4.37	20	5.21	0.23	15	3.91	0.17	9	2.34	0.10	153	39.84	1.74	2	0.52	0.02	4	1.04	0.05	19	4.95	0.22	0	0.00	0.00	0	0.00	0.00	11	2.86	0.13	2	0.52	0.02	0	0.00	0.00	149	38.80	1.70
Terrigal	10.98	32	8.33	0.92	41	10.68	1.17	29	7.55	0.83	151	39.32	4.32	6	1.56	0.17	6	1.56	0.17	93	24.22	2.66	0	0.00	0.00	1	0.26	0.03	4	1.04	0.11	1	0.26	0.03	1	0.26	0.03	19	4.95	0.54
The Entrance	1.96	86	22.40	0.44	54	14.06	0.28	48	12.50	0.24	47	12.24	0.24	8	2.08	0.04	7	1.82	0.04	105	27.34	0.54	0	0.00	0.00	2	0.52	0.01	9	2.34	0.05	5	1.30	0.03	9	2.34	0.05	4	1.04	0.02
The Entrance North	1.26	63	16.41	0.21	40	10.42	0.13	39	10.16	0.13	27	7.03	0.09	10	2.60	0.03	11	2.86	0.04	97	25.26	0.32	0	0.00	0.00	31	8.07	0.10	2	0.52	0.01	1	0.26	0.00	54	14.06	0.18	9	2.34	0.03
Toowoon Bay	0.72	55	14.32	0.10	32	8.33	0.06	32	8.33	0.06	50	13.02	0.09	11	2.86	0.02	6	1.56	0.01	68	17.71	0.13	0	0.00	0.00	28	7.29	0.05	30	7.81	0.06	2	0.52	0.00	34	8.85	0.06	36	9.38	0.07
Toukley	4.08	51	13.28	0.54	33	8.59	0.35	27	7.03	0.29	166	43.23	1.76	10	2.60	0.11	4	1.04	0.04	74	19.27	0.79	0	0.00	0.00	0	0.00	0.00	3	0.78	0.03	13	3.39	0.14	0	0.00	0.00	3	0.78	0.03
Tuggerah	11.58	22	5.73	0.66	26	6.77	0.78	19	4.95	0.57	139	36.20	4.19	12	3.13	0.36	8	2.08	0.24	124	32.29	3.74	0	0.00	0.00	13	3.39	0.39	7	1.82	0.21	4	1.04	0.12	0	0.00	0.00	10	2.60	0.30
Tuggerawong	1.84	25	6.51	0.12	13	3.39	0.06	19	4.95	0.09	211	54.95	1.01	3	0.78	0.01	3	0.78	0.01	87	22.66	0.42	0	0.00	0.00	4	1.04	0.02	4	1.04	0.02	1	0.26	0.00	0	0.00	0.00	14	3.65	0.07
Tumbi Umbi	15.44	14	3.65	0.56	19	4.95	0.76	7	1.82	0.28	258	67.19	10.38	6	1.56	0.24	7	1.82	0.28	67	17.45	2.69	0	0.00	0.00	3	0.78	0.12	3	0.78	0.12	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
Umina Beach	8.38	92	23.96	2.01	38	9.90	0.83	32	8.33	0.70	107	27.86	2.34	16	4.17	0.35	28	7.29	0.61	56	14.58	1.22	0	0.00	0.00	3	0.78	0.07	0	0.00	0.00	5	1.30	0.11	7	1.82	0.15	0	0.00	0.00
Wadalba	4.41	17	4.43	0.20	19	4.95	0.22	18	4.69	0.21	152	39.58	1.75	4	1.04	0.05	22	5.73	0.25	121	31.51	1.39	0	0.00	0.00	22	5.73	0.25	9	2.34	0.10	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
Wagstaffe	0.93	28	7.29	0.07	10	2.60	0.02	1	0.26	0.00	107	27.86	0.26	6	1.56	0.01	7	1.82	0.02	21	5.47	0.05	0	0.00	0.00	0	0.00	0.00	11	2.86	0.03	0	0.00	0.00	0	0.00	0.00	193	50.26	0.47
Wamberal	10.58	24	6.25	0.66	29	7.55	0.80	18	4.69	0.50	148	38.54	4.08	12	3.13	0.33	7	1.82	0.19	93	24.22	2.56	0	0.00	0.00	10	2.60	0.28	4	1.04	0.11	0	0.00	0.00	9	2.34	0.25	30	7.81	0.83
Warnervale	15.43	7	1.82	0.28	6	1.56	0.24	4	1.04	0.16	200	52.08	8.04	1	0.26	0.04	11	2.86	0.44	96	25.00	3.86	0	0.00	0.00	43	11.20	1.73	6	1.56	0.24	5	1.30	0.20	0	0.00	0.00	5	1.30	0.20
Wattanobbi	2.13	46	11.98	0.25	41	10.68	0.23	33	8.59	0.18	113	29.43	0.63	16	4.17	0.09	9	2.34	0.05	112	29.17	0.62	0	0.00	0.00	6	1.56	0.03	2	0.52	0.01	5	1.30	0.03	0	0.00	0.00	1	0.26	0.01
West Gosford	6.41	41	10.68	0.68	52	13.54	0.87	22	5.73	0.37	151	39.32	2.52	12	3.13	0.20	18	4.69	0.30	33	8.59	0.55	0	0.00	0.00	1	0.26	0.02	9	2.34	0.15	10	2.60	0.17	1	0.26	0.02	34	8.85	0.57
Woongarrah	6.33	32	8.33	0.53	40	10.42	0.66	12	3.13	0.20	114	29.69	1.88	7	1.82	0.12	10	2.60	0.16	152	39.58	2.51	0	0.00	0.00	5	1.30	0.08	6	1.56	0.10	4	1.04	0.07	0	0.00	0.00	2	0.52	0.03
Woy Woy	22.90	26	6.77	1.55	24	6.25	1.43	16	4.17	0.95	143	37.24	8.53	38	9.90	2.27	17	4.43	1.01	21	5.47	1.25	0	0.00	0.00	4	1.04	0.24	28	7.29	1.67	23	5.99	1.37	0	0.00	0.00	44	11.46	2.62
Woy Woy Bay	10.65	2	0.52	0.06	5	1.30	0.14	1	0.26	0.03	158	41.15	4.38	90	23.44	2.50	10	2.60	0.28	13	3.39	0.36	0	0.00	0.00	4	1.04	0.11	21	5.47	0.58	27	7.03	0.75	0	0.00	0.00	53	13.80	1.47
Wyoming	8.60	35	9.11	0.78	45	11.72	1.01	25	6.51	0.56	191	49.74	4.28	16	4.17	0.36	7	1.82	0.16	59	15.36	1.32	0	0.00	0.00	1	0.26	0.02	3	0.78	0.07	2	0.52	0.04	0	0.00	0.00	0	0.00	0.00
Wyong	13.52	23	5.99	0.81	25	6.51	0.88	17	4.43	0.60	138	35.94	4.86	9	2.34	0.32	5	1.30	0.18	101	26.30	3.56	0	0.00	0.00	34	8.85	1.20	7	1.82	0.25	15	3.91	0.53	0	0.00	0.00	10	2.60	0.35
Wyongah	1.24	60	15.63	0.19	39	10.16	0.13	31	8.07	0.10	119	30.99	0.39	10	2.60	0.03	5	1.30	0.02	118	30.73	0.38	0	0.00	0.00	1	0.26	0.00	0	0.00	0.00	1	0.26	0.00	0	0.00	0.00	0	0.00	0.00
Yattalunga	0.93	30	7.81	0.07	10	2.60	0.02	8	2.08	0.02	248	64.58	0.60	12	3.13	0.03	15	3.91	0.04	50	13.02	0.12	0	0.00	0.00	0	0.00	0.00	6	1.56	0.01	0	0.00	0.00	0	0.00	0.00	5	1.30	0.01

Central Coast Council

DRAFT GREENER PLACES STRATEGY

Central Coast Council
2 Hely St / PO Box 20 Wyong NSW 2259
49 Mann St / PO Box 21 Gosford NSW 2250
P 1300 463 954
E ask@centralcoast.nsw.gov.au
centralcoast.nsw.gov.au
ABN 73 149 644 003

June 2019