City of Kwinana

Urban Forest Strategy 2026–2046

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City of Kwinana kaditj kalyakool moondang-ak kaaradj midi boodjar-ak ngala nyininy, yakka wer waabiny, Noongar moort. Ngala kaditj baalap kalyakoorl nidja boodjar wer kep kaaradjiny, baalap moorditj nidja yaakiny-ak wer moorditj moort wer kaditj Birdiya wer yeyi.

City of Kwinana acknowledges the traditional custodians of the land on which we live, work and play, the Nyoongar people. We recognise their connection to the land and local waterways, their resilience and commitment to community and pay our respect to Elders past and present.

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Vision

Our vision is to create an expanding urban forest canopy that is evenly distributed for the benefit of everyone, and manage it to remain a sustainable and resilient asset for our communities.

Principles

1. *Value, Protect and Renew*
2. *Expand and Increase*
3. *Monitor, Maintain and Manage*
4. *Engage and Incentivise*

Challenges

- *Poor policy to support tree retention*
- *Pests, diseases and climate change*
- *Urban forest inequity*
- *Data asset management*

Targets

Over 20 years:

Overall LGA: 19.8 to 22.6%

Streetscapes: 10.9 to 22.9%

Parks managed open space: 30.2 to 40.5%

66,000 additional trees LGA wide

1 Urban Forest Context

1.1 Purpose of the Urban Forest Strategy

The Urban Forest Strategy outlines a coordinated and holistic approach to preserve, expand and manage the City's urban forest on both public and private land. The Strategy defines goals and targets for management of the urban forest and prescribes actions to achieve them.

Preserving, growing and managing an urban forest requires a coordinated and organized approach between City Departments and an engaged community to ensure resource requirements are adequately planned for. Significant support exists amongst the Kwinana community to work towards a better urban forest.

This Urban Forest Strategy will guide the City's management of its urban forest canopy through data collection and analysis that enables a coordinated approach to conserve, expand and manage the City's urban forest on both public and private land.

1.1.1 The City's Vision

The City of Kwinana's vision as stated in the *Strategic Community Plan (2021-2031)* is to create "A unique and livable City, celebrated for and connected by its diverse community, natural beauty and economic opportunities".

Our vision is to create an expanding urban forest canopy that is evenly distributed for the benefit of everyone and manage it to remain a sustainable and resilient asset for our communities.

1.1.2 Councils Responsibility

The Kwinana City Council is committed to protecting and enhancing its character and identity through sustainable management of its urban forest, both on public and privately managed land. The City faces many challenges to maintaining and increase its urban forest, pressures that are likely to increase as the City accommodates a rapidly growing population and the uncertainty of a changing climate.

The City of Kwinana has one of the fastest growing populations within any local government area in Western Australia. The City's population is anticipated to almost double by 2036, equating to approximately 45,000 additional people and 15,000 new dwellings, as well as infill and subdivision of existing neighbourhood lots. This growth in the residential population will also be accompanied by considerable expansion of the City's industrial areas and changes to commercial areas. Most of this growth will occur in already defined urban corridors identified in the Metropolitan Region Scheme and reflected in the City's Local Planning Scheme. The clearing and development of the land in these corridors will result in a loss of existing vegetation and canopy cover, and the City has a responsibility to advocate with state government and the property development industry to maximise green cover through better design at the structure planning and subdivision stage.

The Council's overall canopy cover across the LGA is 19.8%. This places Kwinana in a good position compared to many other Councils, and above the 16% average across the Perth metropolitan region. However, focusing on the established urban area, canopy cover is less (16.7%) and industrial areas are very low (6.6%). Kwinana's canopy cover is enhanced by its large areas of remnant bushland and rural areas, that contribute to the 29.6% canopy cover observed on non-urban land. As the urban area expands and the need for space increases, priority needs to be given to protecting as much existing urban forest as possible and fostering better development design.

The City of Kwinana needs to invest strategically in the urban forest in order to generate substantial economic, social, and environmental benefits for the future. As the urban landscape changes, the need to foster a green, sustainable, and resilient community becomes increasingly important. The Council has a major responsibility to manage green infrastructure and ensure its benefits are distributed fairly throughout the community.

1.2 Urban Forestry

1.2.1 What is an urban forest?

'*Urban forests can be defined as all vegetation growing within the urban environment. This consists of two categories: the understory, such as shrubs and hedges up to 3 metres, and the tree canopy, which is any vegetation above 3 metres*.' (Better Urban Forest Planning, WA Department of Planning, Lands and Heritage, 2018).

The trees in urban areas are essential components of a city's green infrastructure and contribute to livable and healthy cities. The City of Kwinana includes private and public trees as part of its urban forest within the urban and rural environments. This forest includes trees and vegetation, vertical gardens and rooftop greenery, and the soil, water, and ecological elements needed to maintain its growth.

Urban forestry involves managing vegetation within an urban setting, which is often a challenging environment for tree growth. This difficulty arises from human activities and the harsh conditions typical of urban areas, such as hard surfaces, nutrient-poor amended soils, and limited below and above-ground space due to services and infrastructure. Consequently, urban forests face numerous challenges that must be addressed strategically and holistically to implement effective management practices and promote resilience.

Although the term urban forest is a collective term, canopy cover is considered an indicator of urban forest health and is often the measure that communities use to set and re-evaluate goals (Heynen 2003). Therefore, trees and canopy cover are the focus of this Urban Forest Strategy.

1.2.2 Benefits of the Urban Forest

Recently, there has been a growing interest in urban forests, leading to increased research, monitoring, and management evaluation. These studies emphasize the importance of diverse and healthy urban vegetation in creating livable cities. Trees and vegetation provide significant economic, social, health, environmental, and aesthetic benefits in urban areas (McPherson et al. 1994, McPherson et al. 1997, Bowler et al. 2010a, Roy et al. 2012, Keniger 2013).

Ecosystem services refer to the benefits that healthy ecosystems provide to humans. Urban trees offer various ecosystem services to cities and their residents, such as temperature reduction and improvements in health and wellbeing. To fully realise these benefits, cities need well-maintained and diverse urban forests.

Trees play a crucial role in delivering air and water filtration, shading, habitat for animals, oxygen production, carbon sequestration, and nutrient cycling. They also connect people to nature. A healthy, well-established urban forest benefits all living organisms by:

- creating shady suburbs for the community with enhanced recreational opportunities,
- providing ecological corridors and habitat for wildlife, and
- improving air, soil and water quality.,

To ensure these benefits are maximised, cities require well managed, healthy, functioning and diverse urban forests.

1.3 Background

1.3.1 History of the Kwinana Urban Forest

1.3.1.1 First Nations/Indigenous History

It is certain that the various indigenous peoples of Western Australia, over the last fifty thousand years living and working closely with our natural environment, came to have a highly developed understanding of the native flora. Food, medicines, tools and personal effects were all obtained from native plants, and fire was used to manage large areas of vegetation for clearing or to encourage regrowth (Carr 1981, Hallam 1975, Hopkins and Griffin, 1989). The City of Kwinana is situated on the traditional lands of the Nyoongar people. It has been home to the Nyoongar people for over 40,000 years, and it lies adjacent to the traditional lands of the Whudjuk and Pinjarup people. Significant Nyoongar camping, hunting, and gathering sites include Sloan's Reserve, Chalk Hill, and The Spectacles. The region around Chalk Hill is part of a network of freshwater lakes and natural springs along the greater metropolitan coastal strip. The Nyoongar people used Chalk Hill to signal their location to others by lighting fires. According to Dreamtime stories, the white chalk on the hill symbolizes the beards of the elders.

To survive, the First Nations peoples had to develop a deep understanding of the natural environment. Before European settlement, the Nyoongars of the Southwest were deeply connected spiritually and economically to the country and had detailed knowledge of what it contained. This knowledge was captured by the six seasons, and the Nyoongar people knew what grew, where and at what time of the year plants could be harvested (Berndt and Berndt, 1979, Carter, 1986). This ecological knowledge was built over millennia and passed on to each new generation. They recognized the six seasons based on climate cues, available resources, and biological phenomena. These seasons are:

Makkuru (maggoro), the winter period between June and July – cold and wet

Djilba (jilba), the spring period between August and September – becoming warmer

Kambarang, the period from October to November – rain decreasing

Birak (birok), the summer period between December and January – hot and dry

Burnuru, the autumn period between February and March – host easterly winds

Djeran (wanyarang), the period between April and May – becoming cooler

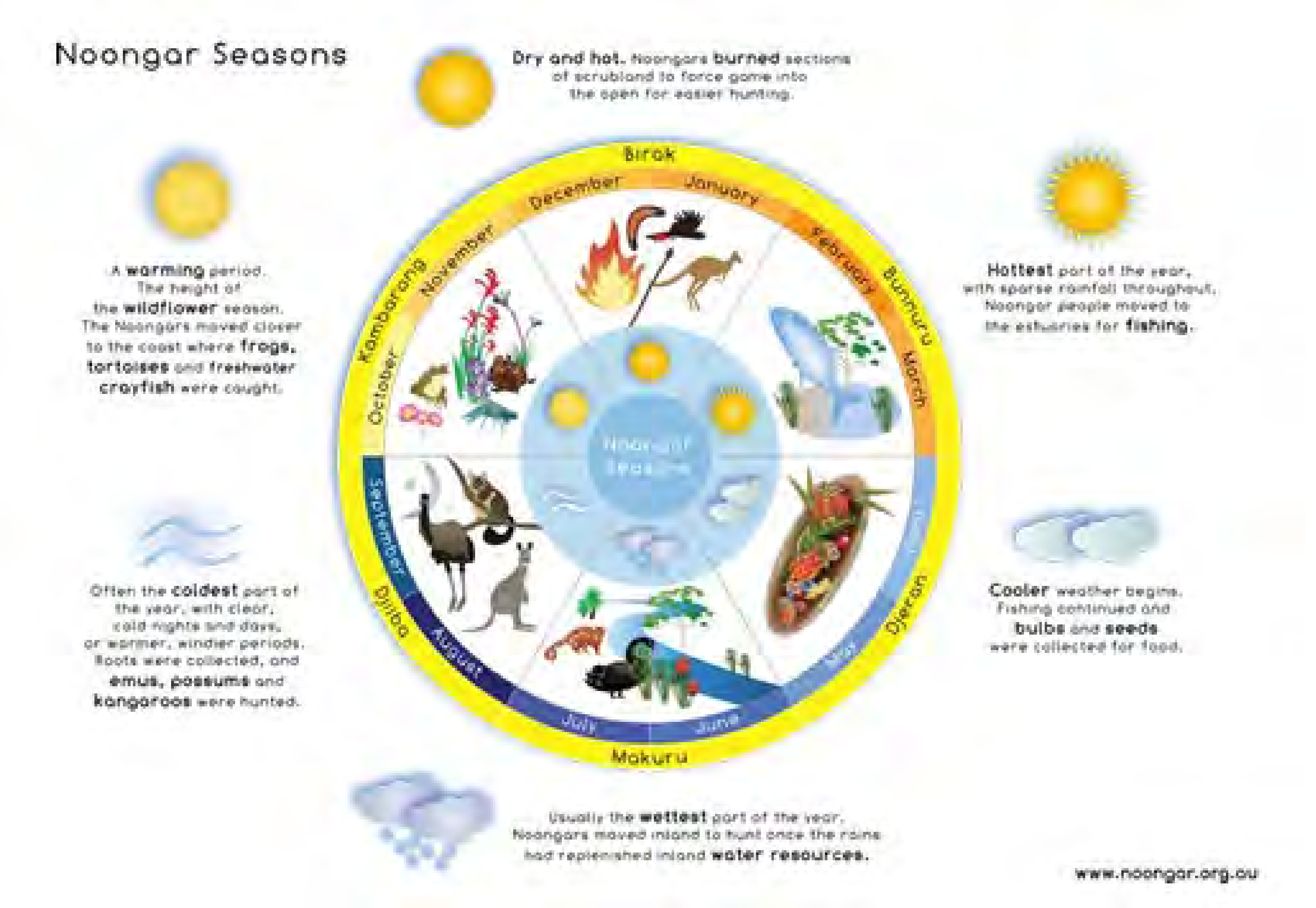


Figure 1: Nyoongar seasons calendar (Source: South West Aboriginal Land and Sea Council).

Understanding these seasons, how they impact the urban forest and their ecological values, and the management tools can be usefully sourced from the Nyoongar people and utilized in the future to help manage the health of the remaining urban forest.

The Nyoongar people of the Swan and Canning Rivers were divided into several different groups. Each group had its territory with specific hunting and cultural rights over specific stretches of the country. These territory rights were inherited through complex systems of kinship. They lived in balance with the natural environment. The main food sources came from the sea, the river systems, and the freshwater lakes between the Darling Scarp. As discussed below, the entry of Europeans to the region has caused significant changes to Country and its management.

In caring for Country, First Nations people draw on laws, customs and knowledge inherited from ancestors over thousands of years. These laws, customs and knowledge ensure the continued health of the lands and seas with which they have a traditional attachment or relationship.

Fire has been integral to most Australian landscapes for millions of years. Because of the long dry summers in the Perth region, fire was a common occurrence from lightning strikes. This has resulted in many fauna and flora developing and evolving a range of physical and behavioural adaptations to survive fire. They depend on it for their persistence. This includes co-existing with fire regimes characterized by intensity, frequency, burning scale, and season. When the Nyoongar people arrived 40-60,000 years ago, they took over as the primary cause of ignitions. They burnt for various reasons, including access, to promote food and to hunt. Their use of fire is governed by the customs and lores, which are dictated by weather and season, soil and vegetation types, water cycles, and natural features in the landscape such as wetlands, waterbodies, rivers and rocky outcrops. As a result of their fire use at different intensities and frequencies over thousands of years, they have maintained diverse ecosystems and kept them healthy and in balance.

Since European colonisation, traditional burning practices have been severely disrupted, and many landscapes have undergone significant change with the establishment of permanent communities, infrastructure, industries and agriculture. Much of the remnant bushland is fragmented and subjected to invasive species, influencing how, when, where and how frequently fire is used.

The vegetation of the City of Kwinana before European settlement was broadly characterised by Beard (1990) (Figure 2, Table 1).

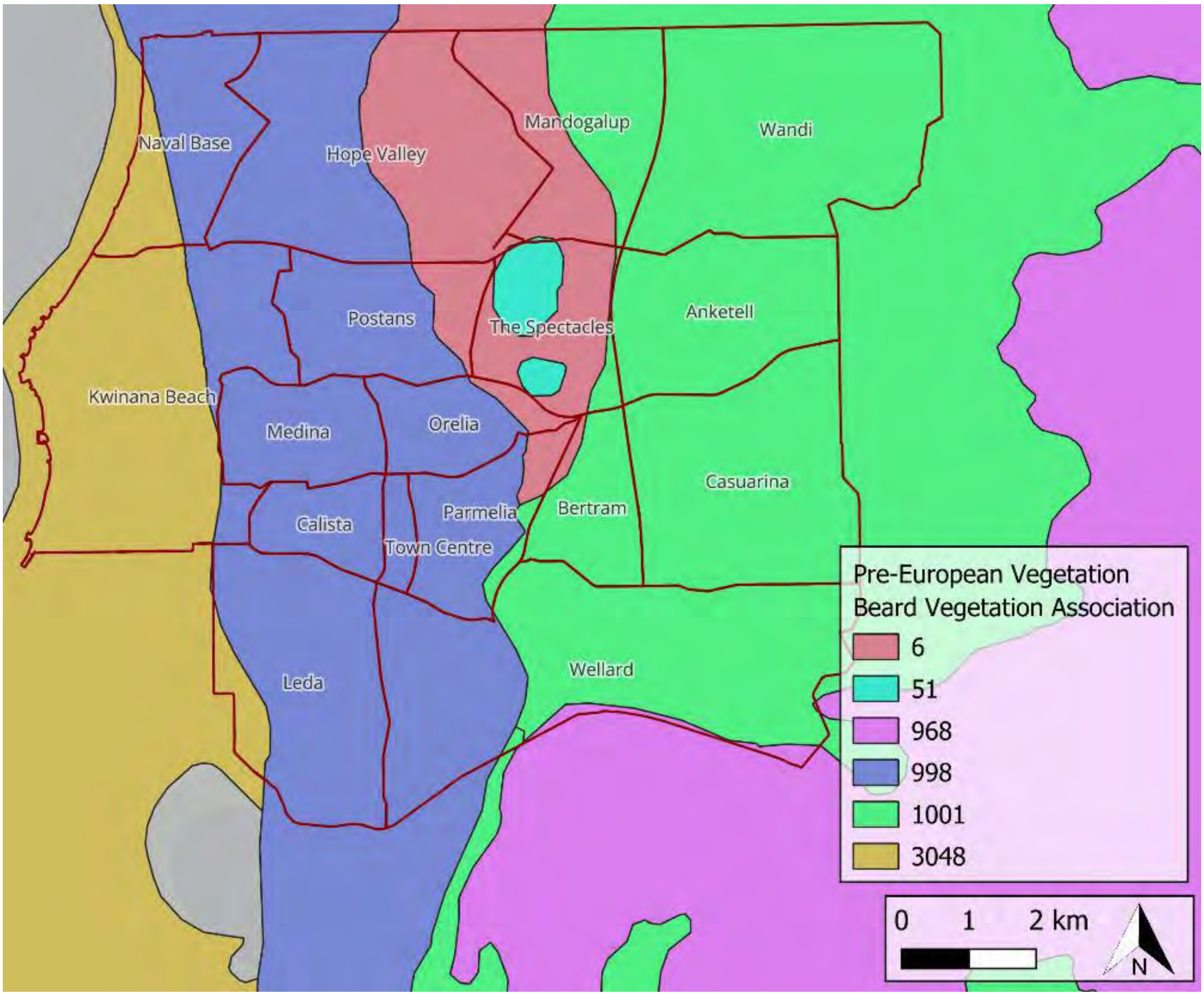


Figure 2: Vegetation types present prior to European settlement (Beard 1990).

Table 1: Vegetation associations present prior to European settlement associated with the different soil types present in the City of Kwinana.

System	Vegetation Association	Vegetation Type	Structure Description	Vegetation Description
SPEARWOOD	51	33	Sedgeland	Cyperacea, Restionaceae, Juncaceae (mainly in the South-West)
BASSENDEAN	1001	7	Low forest, woodland or low woodland with scattered trees	*Eucalyptus marginata*, *Banksia* spp., *Allocasuarina* spp.
SPEARWOOD	6	3	Woodland southwest	*Eucalyptus marginata*, *Corymbia calophylla*, *E. wandoo*.
PINJARRA	968	3	Woodland southwest	*Eucalyptus marginata*, *Corymbia calophylla*, *E. wandoo*.
SPEARWOOD	998	3	Woodland southwest	*Eucalyptus marginata*, *Corymbia calophylla*, *E. wandoo*.
ROCKINGHAM	3048	18	Scrub-heath	Mixed heath with scattered tall shrubs *Acacia* spp., Proteaceae, and Myrtaceae.

1.3.1.2 Post-Colonisation History of Kwinana Urban Forest and Current Land Use

Together with earlier activities such as agriculture and horticulture, the early (1800s) and subsequent developments impacted the local Nyoongar people of the Kwinana area. Like most First Nations groups across WA, they encountered assimilation and segregation policies, negatively impacting their living locations, movement throughout country, and their quality of life. However, to this day, despite the significant changes to the landscape, many Nyoongars continue to obtain sustenance, knowledge and spiritual renewal from the rivers, lakes and sea. The Nyoongar people are the custodians of the City of Kwinana and have a proud, strong, and significant cultural presence.

The City has one of the highest percentages of Aboriginal and Torres Strait Islander populations in the Perth metropolitan region, with its rich cultural Nyoongar community history highly valued. The City has committed firmly to ongoing conciliation by developing the *Innovate Reconciliation Action Plan* (*2020 – 2022)*, following the completion of the *Reflect Reconciliation Action Plan 2019*. The City recently established a new council committee, the Boola Maara Aboriginal Consultative Committee (BMACC), which is an advisory committee to Council and is the first of its kind in WA. The Committee is responsible for providing advice on matters that impact local Aboriginal communities. The BMACC has been engaged to ensure they have received communication on the findings and implications of the Urban Forest Strategy.

Europeans started settling in the Kwinana area in the 1830s, focusing on farming. Significant residential development did not occur until the 1950s. As well as a growing residential area, the City has substantial industrial, and rural areas and some commercial areas. The City has been the home of traditional heavy industries, including the BP Kwinana oil refinery, many other associated petro-chemical companies, mineral refineries, power stations, chemical plants, cement works and a range of supporting industries. It has a busy industrial water bulk port, and the City is the home to the Fremantle Ports Outer Harbour. This consists of, from north to south, the Alcoa Jetty, the Kwinana Bulk Terminal, the BP Oil Refinery Jetty, the Kwinana Bulk Jetty, and the CBH Grain Jetty. Other secondary industries include service fabrication, construction, engineering and maintenance for the adjacent heavy industries. The area is now approaching land availability capacity, and the current extent of native vegetation is a fraction of its pre-colonisation extent (Figure 26).

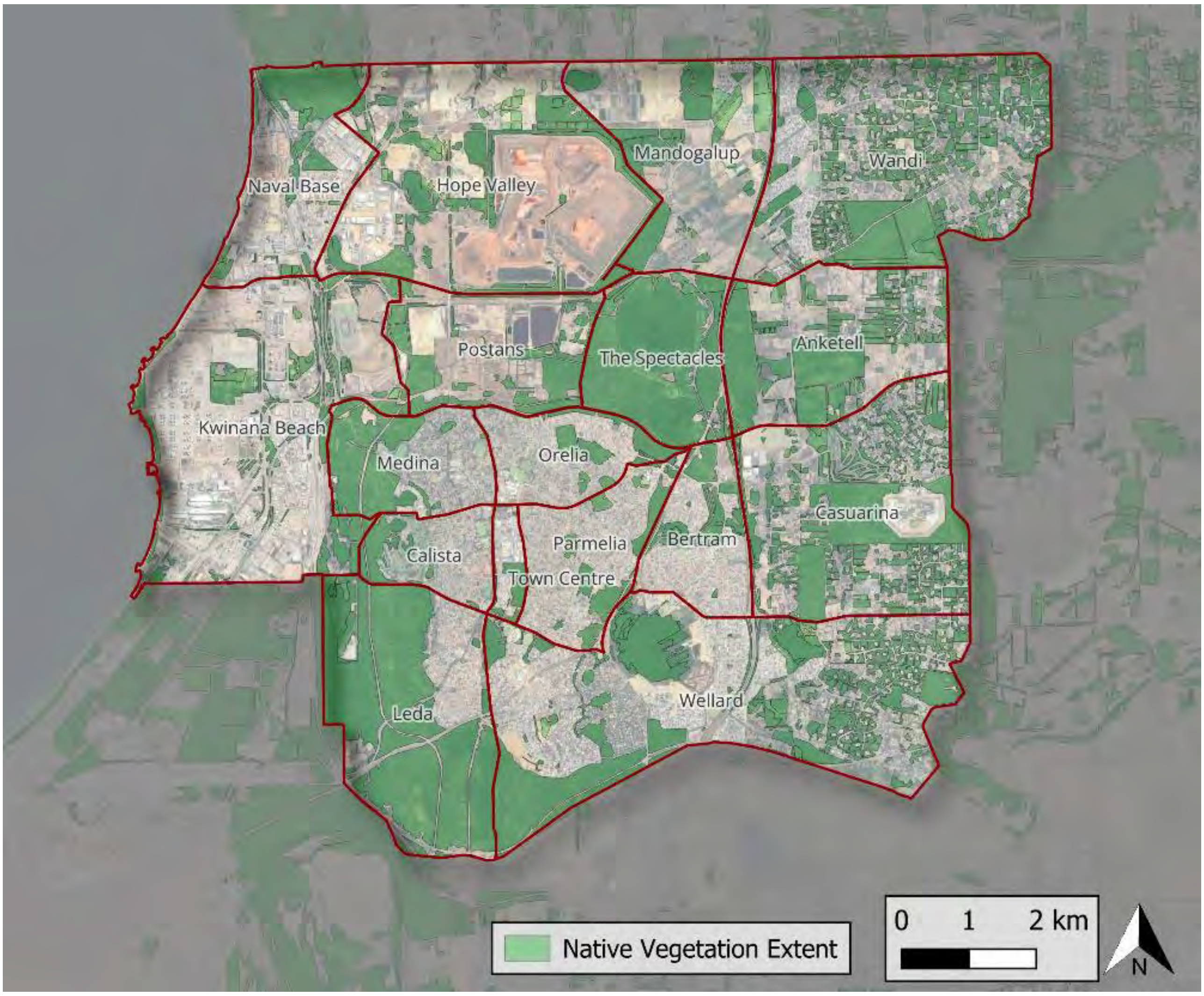


Figure 3: Current extent of native vegetation in the City of Kwinana (Beard 1990).

1.3.2 Ecology

The average, maximum and minimum elevations within the City are 17m, 65m and -3m, respectively. There are four major soil types in the City; these are aeolian deposits and, from the east to the west, consist of the Bassendean, Karrakatta, Cottesloe and Quindalup sands (Figure 30); the last three overlay limestone. The Bassendean system consists of undulating dunes of well-bleached white, grey sands, calcium carbonate, and the base material for limestone, which has long since been leached out and washed away. The Basendean soils are frequently referred to as 'gutless' sands. The Karrakatta system consists of an undulating landscape of deep yellow sands. The Cottesloe system is a low hilly landscape with shallow brown or yellow sand with limestone close to the surface. The Quindalup system comprises white calcareous sand dunes and beach ridges along the coast. Running through the middle of the City are three small peaty swamps that are part of the Herdsman system. These soil types correlate well with Beard's vegetation types (see Figure 2). In addition to the species described in Table 1, the Bassendean soils support *Banksia attentuata, B. menziesii, B. illicifolia* on moist sites, and *Adenanthos cygnorum* can be a useful identifier of this soil type. Karrakatta soils support *Allocasuarina fraseriana, Xanthorrhoea preissi, and* understory species such as *Acacia pulchella, Conostylis* spp. and *Hypocalymma robustum.*

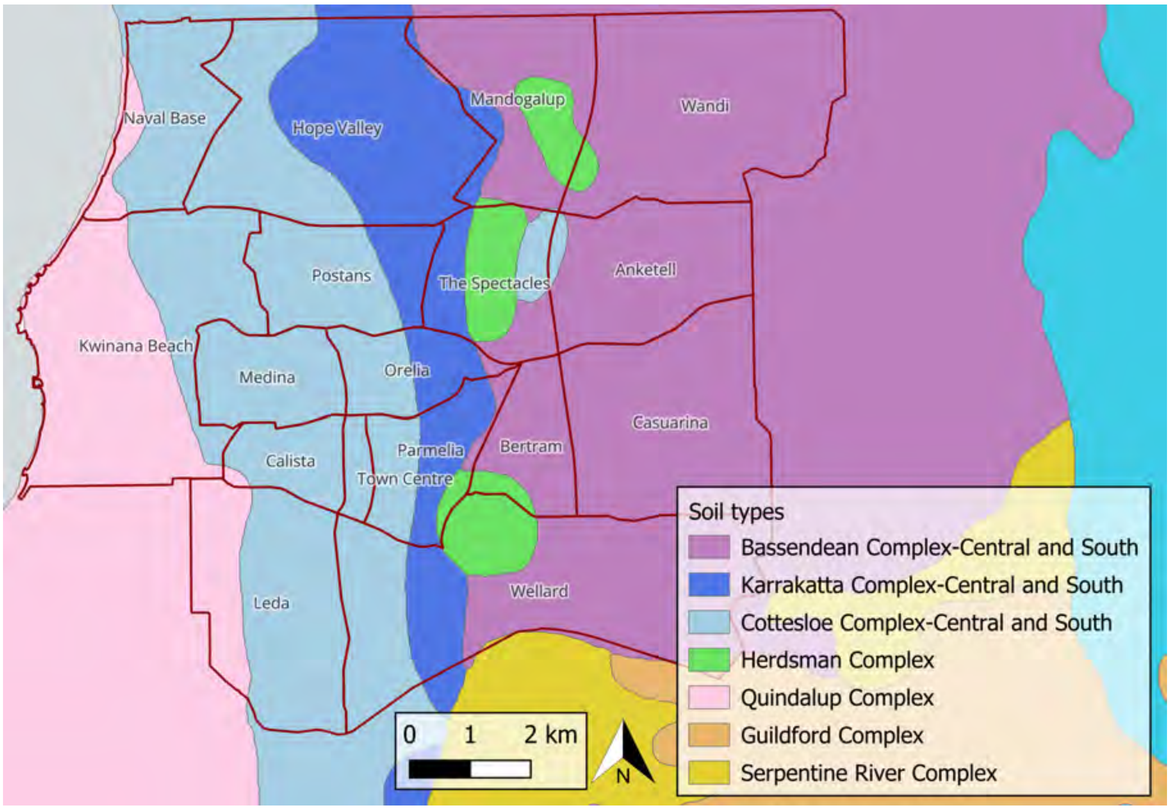


Figure 4: Soil types of the City of Kwinana.

The City's climate is Mediterranean, with warm, dry summers and wet, cool winters. The warm season is from December to March, with an average daily high temperature of 27°C. The hottest month is February, with an average high of 29°C and low of 18°C. The cool season lasts 4 months, from May to September, with an average daily high below 19 °C. The coldest month is July, with an average low of 9°C and a high of 17°C.

(Figure 5).

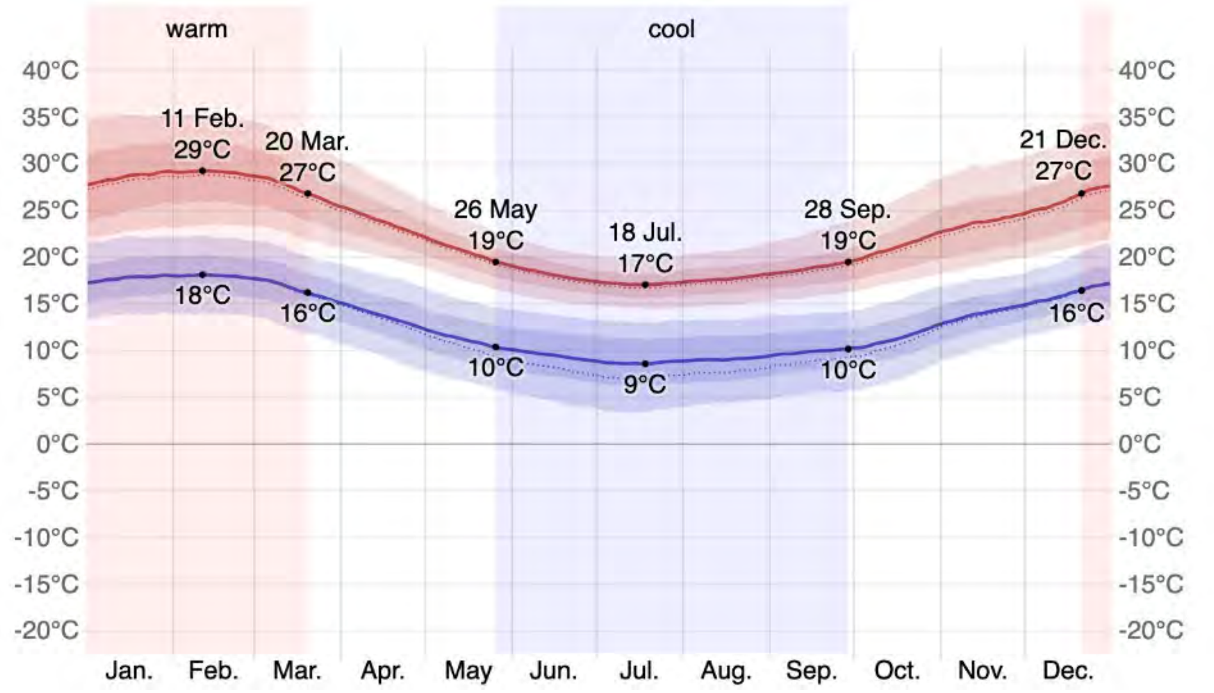


Figure 5: Average high and low temperatures in Kwinana (Source: WeatherSpark.com)

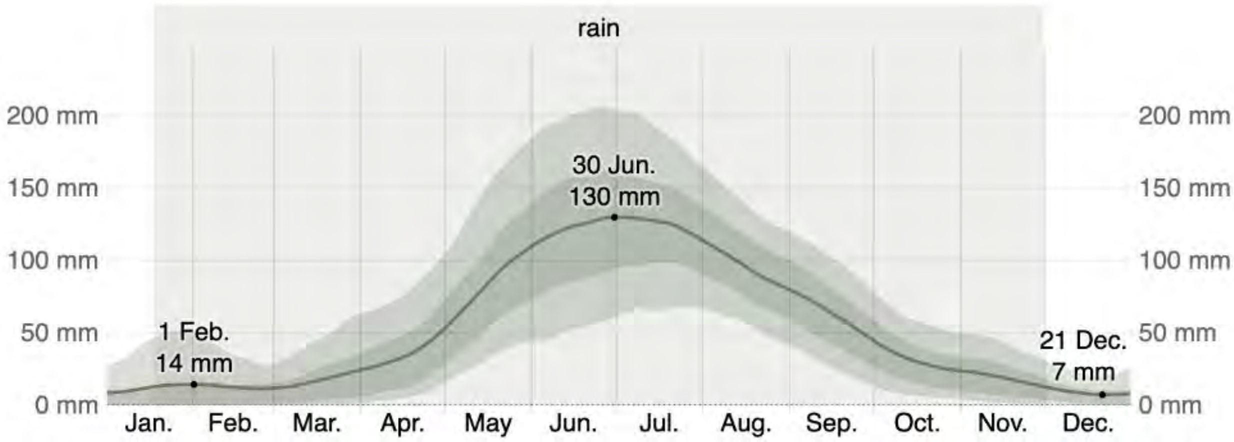


Figure 6: Average monthly rainfall in Kwinana (Source: @WeatherSpark.com)

The dry season in Kwinana lasts approximately 7.3 months, from 28th September to 6th May, with January having the fewest wet days. The wetter season lasts 4.7 months, from 6th May to 28th September, and the month with the most wet days is July (Figure 7).

1.3.3 Predisposing, Inciting and Contributing Factors of Tree Decline

When considering the health of the urban forest, a valuable tool is Manion's (1981) Tree Decline Spiral' (Figure 7). It provides a range of biotic and abiotic factors that can contribute to tree decline and, in some cases, eventually death. The factors highlighted in the figure are in no way complete, and other factors can be included depending on the environmental, climatic, and biotic conditions. For example, the Polyphagous Shot-Hole Borer was recently introduced to the Perth metropolitan region, and at the time of this Strategy development has been identified in localities adjacent to the City of Kwinana (DPIRD 2024). The beetle and its associated fungus (*Fusarium* sp.) can be included in the spiral. If the invasive fungus Myrtle Rust develops in trees, it could also be included. Such knowledge will assist in the management of trees. The southwest of Western Australia has become warmer and drier in the last 50 years, leading to more trees showing canopy dieback or even death. A good example was in 2010/11 when a dry winter followed by a long hot summer resulted in tree declines. A similar event was seen over the warm season of 2023/2024 with the hottest summer on record with thirteen days over 40ºC; even in April, there was a day over 37ºC. This event followed 2023's spring heat waves, which broke monthly maximum and minimum temperatures in September and November. These events can predispose trees to opportunistic fungal pathogens and insects, further exacerbating the decline syndrome.

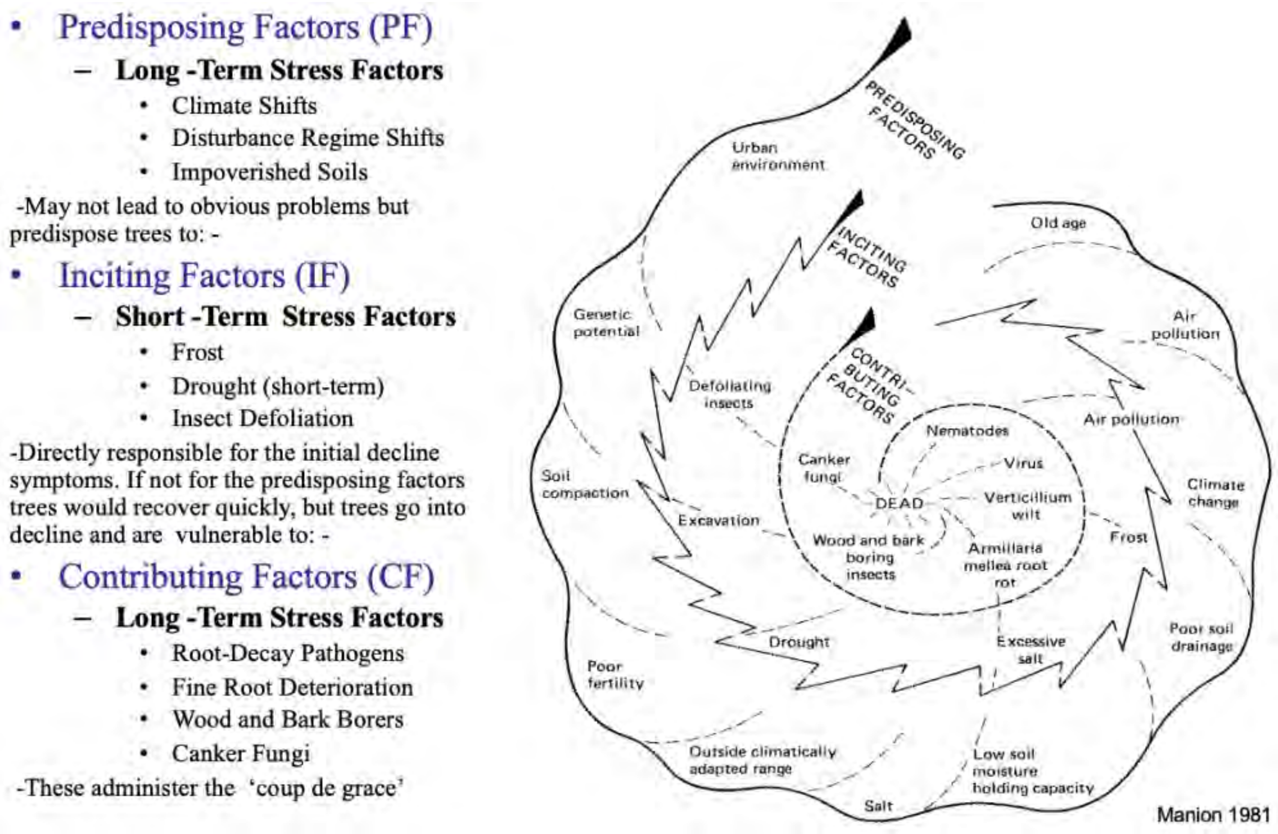


Figure 7: The Tree Decline Spiral highlights some of the predisposing, inciting and contributing factors that can cause trees to decline and eventually die (Source: Manion 1981).

In addition to the genuine future impacts of a changing climate, past and present anthropogenic activities are major contributors to declining trees. Examples are shown in Figure 8, with fragmentation as an additional predisposing factor. Continued removal of canopy cover due to development can result in the heat island effect, which places trees under further stress, allowing inciting and contributing factors to gain a foot hold. Mycorrhizal fungi play a significant role in the health of many tree species, particularly members of the Myrtaceae. Loss of mycorrhizal diversity and richness due to climate change and anthropogenic activities has contributed to the declining health of trees. Sapsford et al. 2017 highlighted the range of abiotic and biotic stressors that can be linked to declining trees and loss of beneficial mycorrhizal fungi (Figure 8), all of which are relevant to the urban forest in the City of Kwinana. Although the Environmental Protection Authority (EPA) and the Department of Water and Environmental Regulation (DWER) has strong environmental controls in place around the industrial activities in the City, it is still of value to consider the potential links of past and present aerial, water and soil pollutants in adjacent areas where trees are in decline. This is particularly true as diagnostic and analytical techniques improve over time.

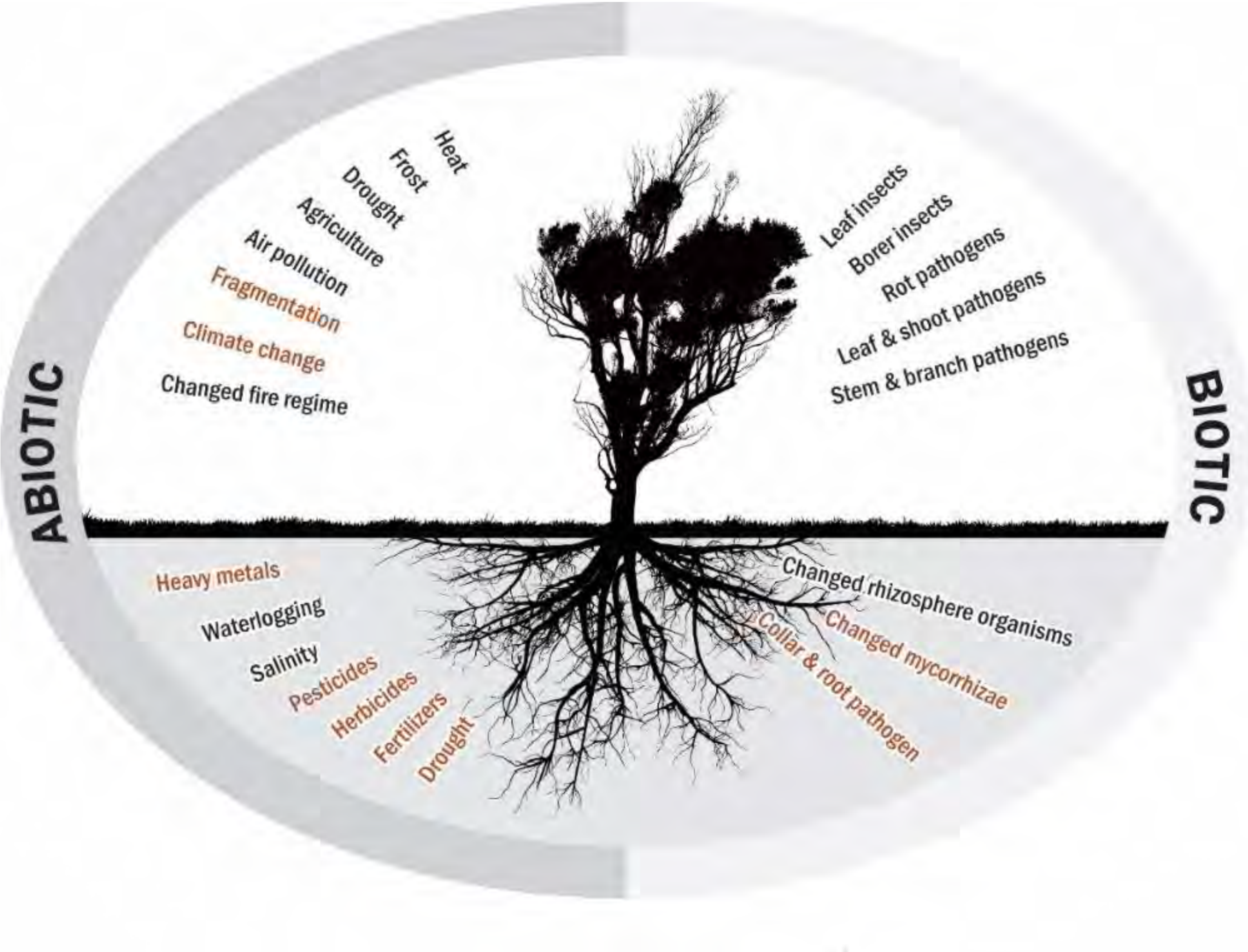


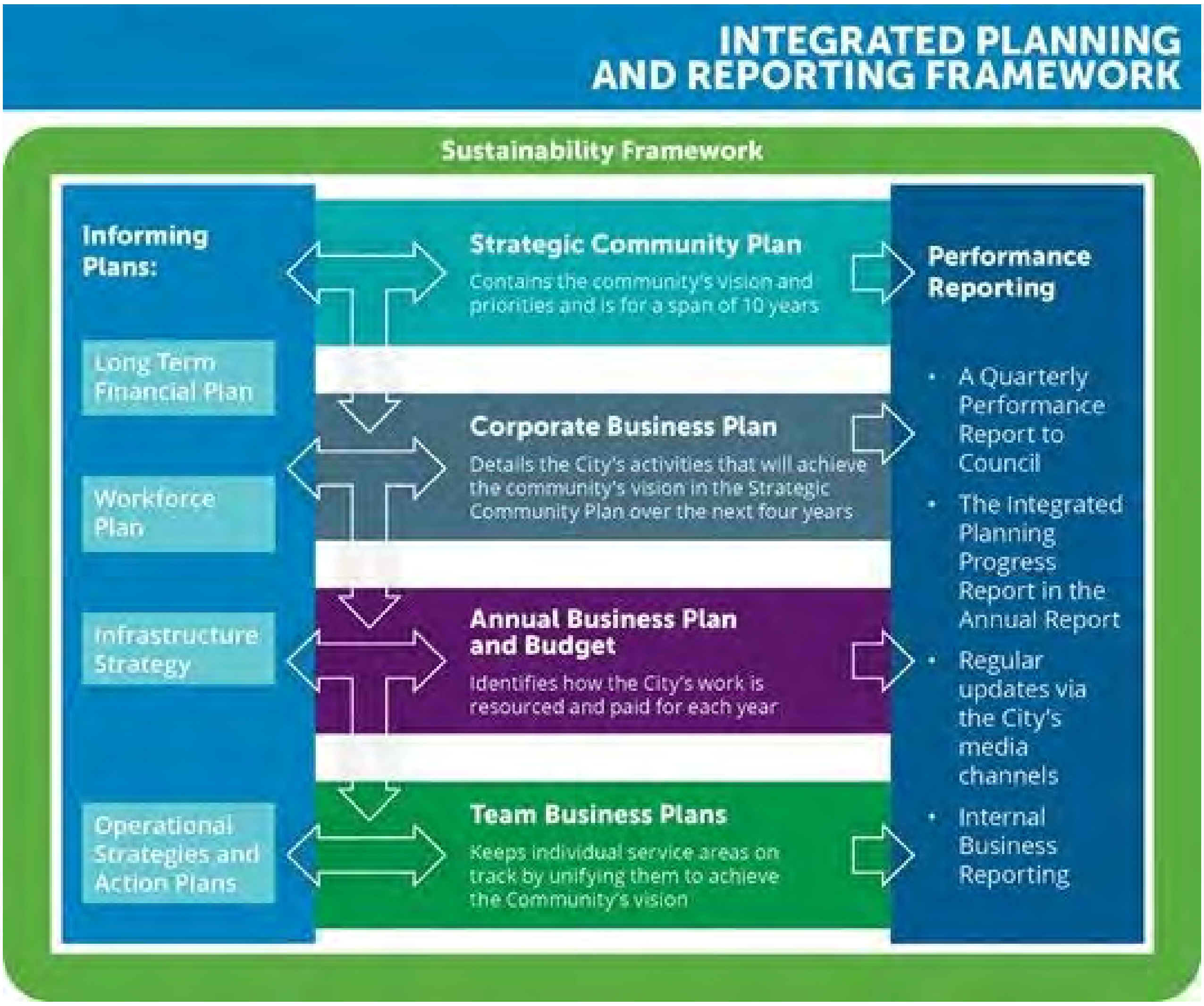
Figure 8: Abiotic and biotic factors linked to tree declines with an emphasis on tree decline and loss of mycorrhizae (Sapsford et al. 2017).

An important predisposing factor in the Australian landscape is the change in fire regimes. Many animal and plant species have evolved with fire, and since European settlement the fire regimes have changed substantially, and can be considered a disturbance regime shift, hence a predisposing factor. This is especially true in small remnant pockets of bushland such as those present in the City of Kwinana. It is also interesting to note that Manion considered the urban environment a predisposing factor, an important point when considering the life expectancy of tree species growing throughout urban landscapes.

2 Strategic Review and Context

Integrated planning and reporting provide local governments with a structure for converting community goals and aspirations into actionable objectives while monitoring progress in achieving these goals. The City of Kwinana follows the Integrated Planning and Reporting Framework as specified by the *Local Government Act 1995 and the Local Government (Administration) Regulations 1996*. These regulations require local governments to have a "Plan for the Future."

The Council has developed several operational strategies and plans that support urban greening concepts and their impacts, most notably the Climate Change Plan and Environment Strategy. The main drivers of the Urban Forest Strategy are the *Strategic Community Plan* (*SCP*) and the *Corporate Business Plan* (*CBP*).



2.1 Strategic Community Plan (2021 – 2031) and Corporate Business Plan (2021 – 2025)

Strategic planning in the City of Kwinana is driven by the *Strategic Community Plan 2021 -2031*, which is underpinned by the *Corporate Business Plan 2021 - 2025*, budgets and business plans. Western Australian legislation requires all local governments to adopt a *Strategic Community Plan*, which is the overall guiding document of the community's vision for Kwinana, and a *Corporate Business Plan*, which directs how the City will achieve its *Strategic Community Plan* by detailing actions, projects and programs. The Urban Forest Strategy is an operational strategy that was a commitment within the *Corporate Business Plan* and supports the vision and outcomes of the *Strategic Community Plan*.

The *SCP* is the City's guiding document of the community's vision for Kwinana's future. The *CBP* activates the objectives in the *SCP*.

- Outcome 1: A naturally beautiful environment that is enhanced and protected
    - Objective 1.1 – Retain and improve our streetscapes and open spaces, preserving the trees and greenery that makes Kwinana unique.
        - Relevant actions from the *CBP*:
            - Review of the Streetscape Upgrade Strategy
            - Review of the Parks Upgrade Strategy
            - **Develop the Urban Forest Plan**
    - Objective 1.2 – Maintain and enhance our beautiful, natural environment through sustainable protection and conservation.
        - Relevant actions from the *CBP*:
            - Implement the Local Biodiversity Strategy
            - Develop and implement the Pilot Environmental Stewardship Program
            - Update and implement the *Natural Areas Management Plan*
            - Implement the *Local Planning Strategy* and prepare the *Local Planning Scheme*
            - Implement the *Sustainable Water Management Plan* (The Water Plan)
            - Implement the *Climate Change Plan*

2.2 Local Planning Strategy (2022 – 2036)

The City of Kwinana's Draft *Local Planning Strategy* (*LPS*) sets out strategic Directions and Actions for land use planning and development for a 15-year horizon (2036). A key element of the Local Planning Strategy in terms of sustainable development, livability, character and resilience is the environment. This ranges from enhancing and retaining tree canopy cover in suburban areas, to the protection of ecological linkages and adapting to climate change.

Key directions of the LPS relevant to the urban forest are to:

- Enhance and retain tree canopy cover to cool residential streets and open spaces during extreme heat, provide shade to encourage walking and cycling, create leafy neighbourhoods, and enhance local biodiversity; and

- Identify ecological linkages which link locally and regionally significant natural areas and provide stepping-stones for flora and fauna. These linkages would support the ongoing management of regional sites and provide opportunities for integrated walking trails with interpretive signage.

2.3 Environment Strategy (2024 – 2034)

The purpose of the *Environment Strategy (2024 - 2034)* is to deliver the environmental objectives of the *Strategic Community Plan*.

There are two objectives in the SCP that will be delivered through the Environment Strategy. These are:

1. Retain and improve our streetscapes and open spaces, preserving the trees and greenery that makes Kwinana unique

2. Maintain and enhance our beautiful, natural environment through sustainable protection and conservation.

The *Environment Strategy* has four key directions:

- Livability - strengthen our communities' resilience to the projected impacts of climate change, create a greener city, protect the cultural heritage of Kwinana and increase active transport access for all our community.
- Decarbonisation – achieve Net Zero corporate emissions by 2035 and become a Net Zero city by 2050.
- Biodiversity – protect, enhance and restore our regions biodiversity and manage water systems in an environmentally responsible manner.
- Circularity - drive the creation of a circular economy for our community

The *Environment Strategy* is an overarching document that informs a number of developing and existing plans and strategies, including the Urban Forest Strategy.

2.4 Streetscape Upgrade Strategy (2019 – 2029)

The *Streetscape Upgrade Strategy (2019 – 2029)* is a long-term plan to guide the design and management of landscaping within the City's streets to ensure that they are upgraded and maintained to an appropriate standard. The Strategy builds a case for the Urban Forest Strategy.

The Streetscape Upgrade Strategy is structured around three key goals, the first of which is that 'all streets in the City of Kwinana will be green and shaded with well managed trees suited to their location'. To achieve this, the plan set out several objectives:

- Protect existing trees
- Manage and replace ageing trees
- Increase canopy cover and plant new trees
- Better Manage the Urban Forest

Which will be achieved by three strategies:

- Strategy 1.1 - Collect and maintain tree asset data
- Strategy 1.2 - Create an Urban Forest Plan
- Strategy 1.3 - Street Tree Planting Program

In addition, the City's urban greening aspirations are guided and supported by several other documents and their outcomes.

- *Climate Change Plan 2021 – 2026*
- *Sustainability Framework 2023*
- *Local Biodiversity Strategy 2022*

- *Environment Strategy 2024*
- *Water Plan 2024 – 2028*
- *Local Planning Policy No. 1 Landscape Feature and Tree Retention*
- *DRAFT Local Planning Policy No. 2 Streetscapes*
- *Policy - Street Trees and Verge Treatments*
- *Policy - Pruning and Removal of Trees on City Managed Land*
- Existing Urban Forest

2.5 Current State

2.5.1 Existing Tree Species and Counts

Although the City does not have a suitable Tree Audit database that can be analysed for this Urban Forest Strategy, it does have a record of all trees planted by the City since 2015. A total of 2066 trees across 27 genera and 52 species have been planted. The most common species planted was *Agonis flexuosa* (Wonil or WA Peppermint) (n=451), followed by *Eucalyptus caesia* (gungurru or silver princess) (n=222), *Jacaranda mimosifolia* (Jacaranda) (n=177)*, Corymbia calophylla* (marri) (n=156)*,* and *Liquidambar styraciflua* (Liquidambar) (n=132)*.* The family Myrtaceae dominates the planting with *Eucalyptus* comprising more than 25% of the population.

2.5.2 Current Canopy Cover

In March 2023, City of Kwinana engaged ArborCarbon to acquire, process and deliver remotely sensed data over Kwinana that has been used to determine current canopy cover, available planting space, land surface temperature, and provide insight into where the Council should be targeting their efforts to increase canopy.

The following baseline canopy cover data has been used to determine the canopy cover targets in Section 5.

2.5.2.1 Locality, Tenure and the total LGA

The total canopy cover at across the Kwinana LGA at the time of acquisition was measured at 19.8%.

In general, localities in the north-west, such as Kwinana Beach, Naval Base and Hope Valley, have the lowest canopy cover (Figure 9). These areas are mostly used for Industrial purposes. Both Leda and The Spectacles have high canopy cover, correlating with their high proportion of densely vegetated Bush Forever sites. Medina, Orelia, Calista, Parmelia, and Bertram mainly comprise of Residential land, and range between 11.6% canopy cover (Bertram) to 32.4% (Medina). Mandogalup, Wandi, Anketell, Casuarina, and Wellard are largely considered Rural and therefore have reasonable canopy coverage (16.2 – 28%). However, a large proportion of this land is classified as Development, and these Localities are likely to undergo significant canopy reduction as a result. Although Wellard and Wandi had moderate proportional canopy cover, they contributed significantly to the City's overall canopy cover (450 ha and 294 ha respectively) (Figure 10) due to their overall size and land use (a larger portion of each locality is used for Rural purposes).

A larger proportion of land in Kwinana is privately managed (7800 ha) compared to publicly managed (4000 ha) (Figure 11). Approximately 17% of privately managed land is canopy cover, and 24% of public land is canopy cover.

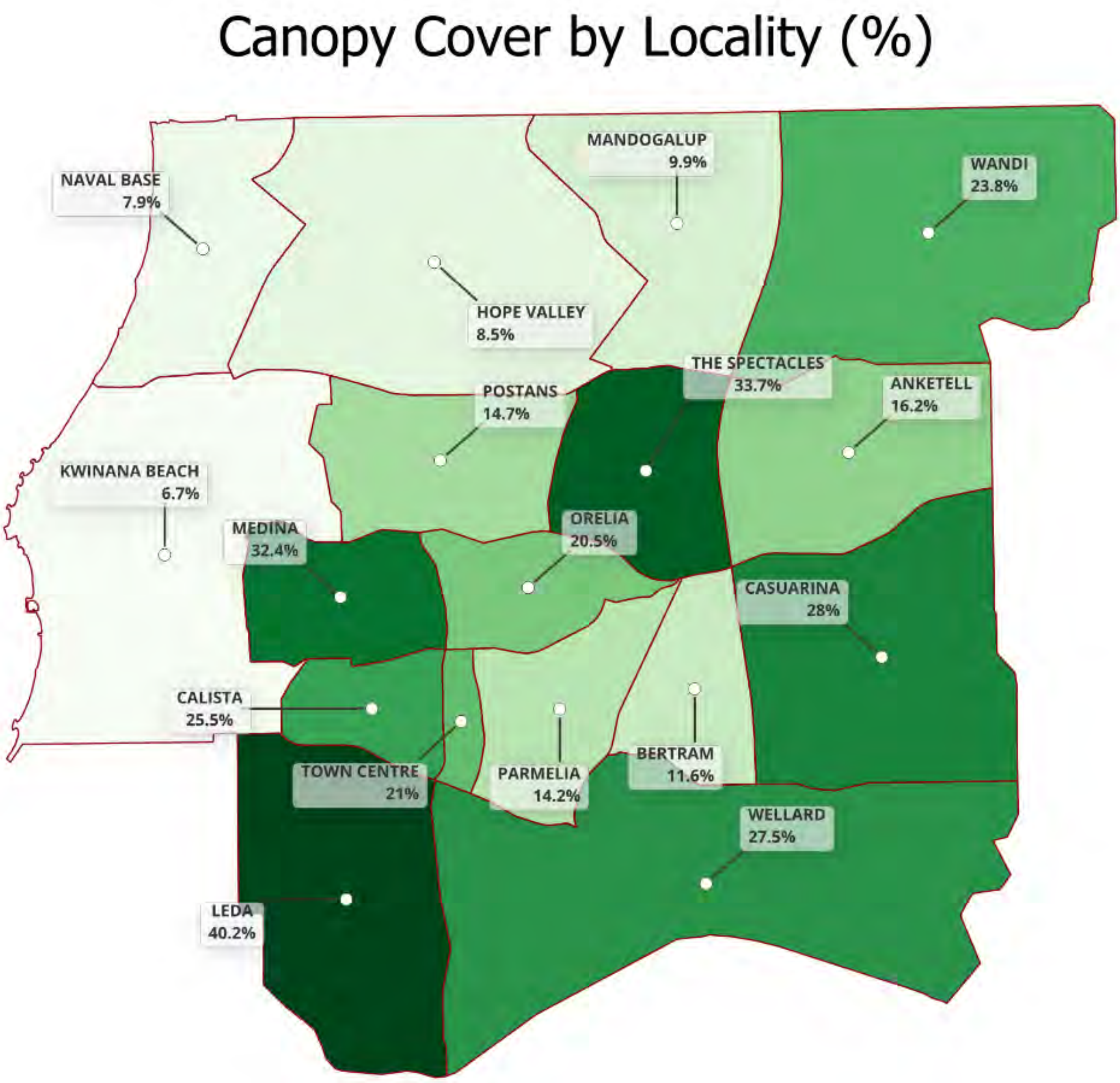


Figure 9: Proportional canopy cover of Localities, coloured low canopy as light green to high canopy cover as dark green.

Figure 10: Proportional canopy cover of each Locality (left), and contribution of each Locality to overall canopy cover (right).

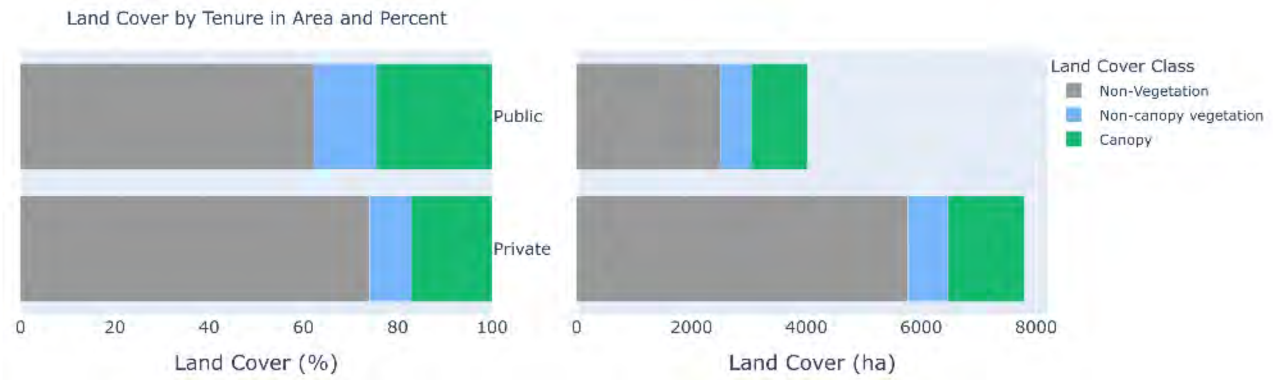


Figure 11: Land cover classification proportion (%) (left) and hectare coverage (right) of the land tenure in City of Kwinana.

2.5.2.2 Land Use

Canopy cover statistics were extracted from a Land Use Boundary (Figure 12) that was developed for this project (see Appendix A for details of its development). Several of these categories are further broken down as required. These Land Use categories are used to inform the canopy cover targets in Section 5.

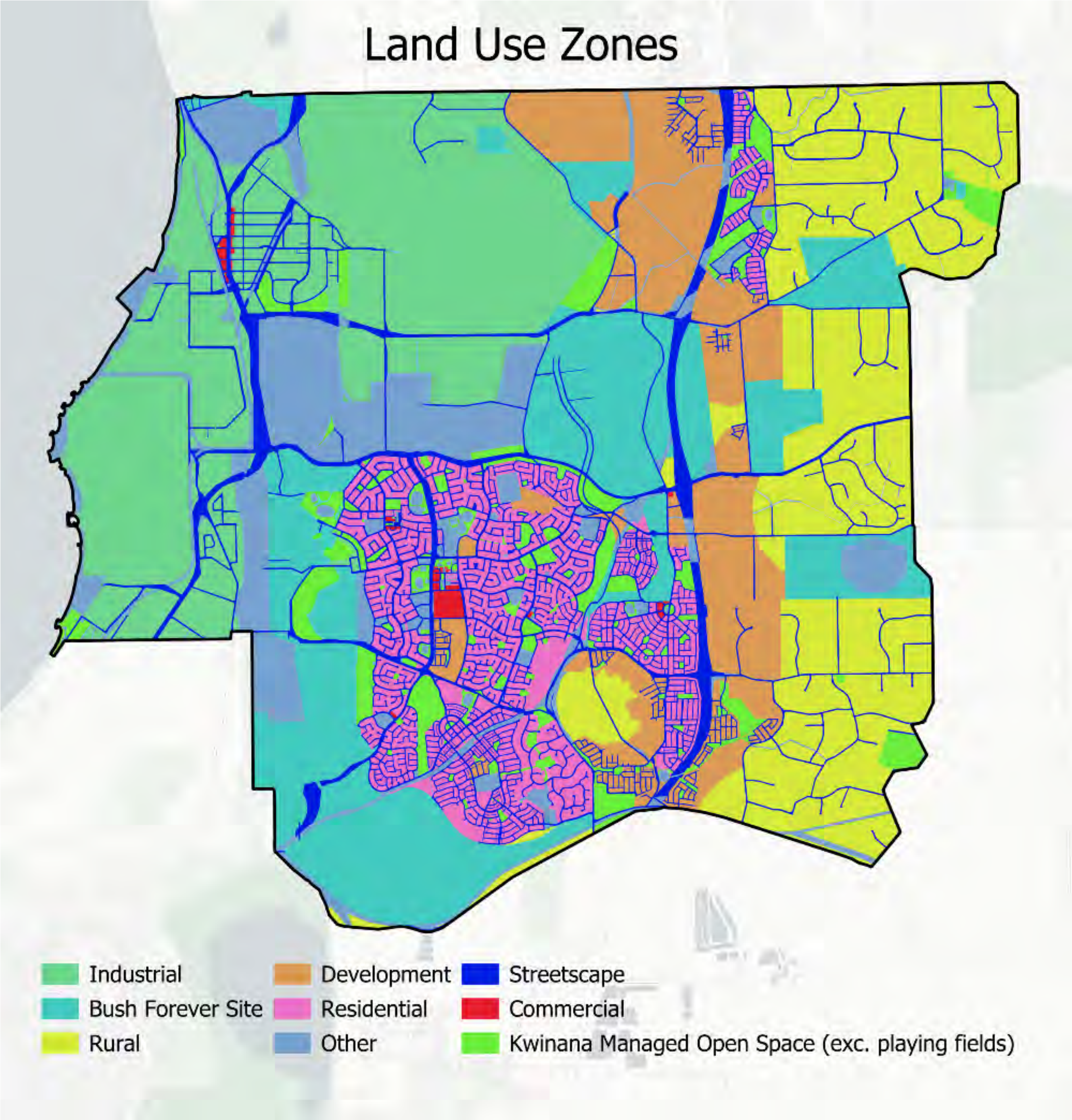


Figure 12: Land Use categories used to determine canopy cover.

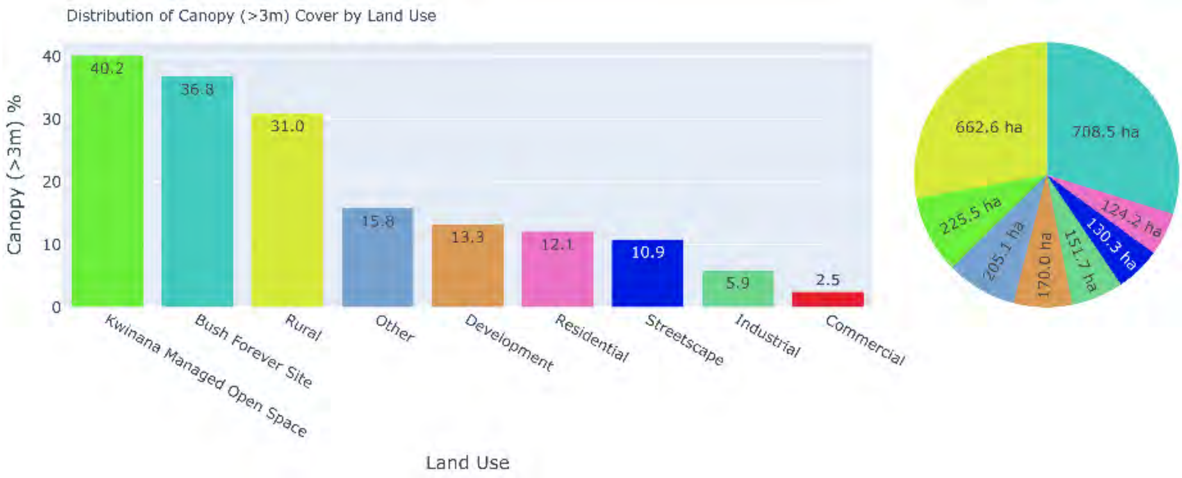


Figure 13: Proportional canopy cover of each Land Use zone (left), and contribution of each Land Use zone to overall canopy cover (right).

Kwinana managed open space had high proportional canopy cover (Figure 13), but covers little area (approximately 500 ha, Figure 14), therefore contributes less to the overall canopy cover of the LGA compared to Bush Forever Sites and Rural land, which together make up over half the LGAs canopy cover (1371.1 ha). The land use type that covers the most area in Kwinana is classified as Industrial (Figure 14), however, this land zone has low proportional canopy cover (5.9%, Figure 13) and it contributes little to the LGAs overall canopy cover (151.7 ha).

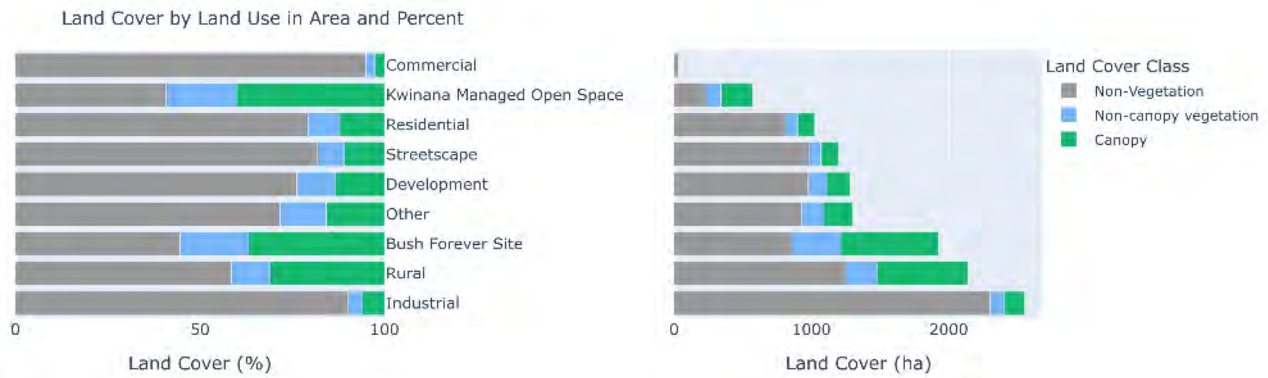


Figure 14: Land cover classification proportion (%) (left) and hectare coverage (right) of the Land Use zones in City of Kwinana

2.5.2.3 Kwinana Managed Open space

Kwinana managed open space was separated into Open Space managed by the Parks Team, open space managed by other departments (e.g. Natural Areas) and those managed by other organisations (e.g. Developers). As seen in Figure 15, the majority of the Open Space is concentrated around the residential areas where most of the community reside, and less around the Industrial and Rural areas. The canopy cover of Open Space managed by the Parks Team was assessed and presented in Figure 16. There was only two small parks categorized as Local open space totaling 0.3 ha in size, which has 35.5% canopy cover. However, since the land area of this category is so small, Local open space did not contribute to overall canopy cover of Parks managed open space (Figure 16). Open Space classified as Regional makes up most of the open space in Kwinana, has high canopy cover (31.9%) and also contributes the most canopy cover (36.2 ha).

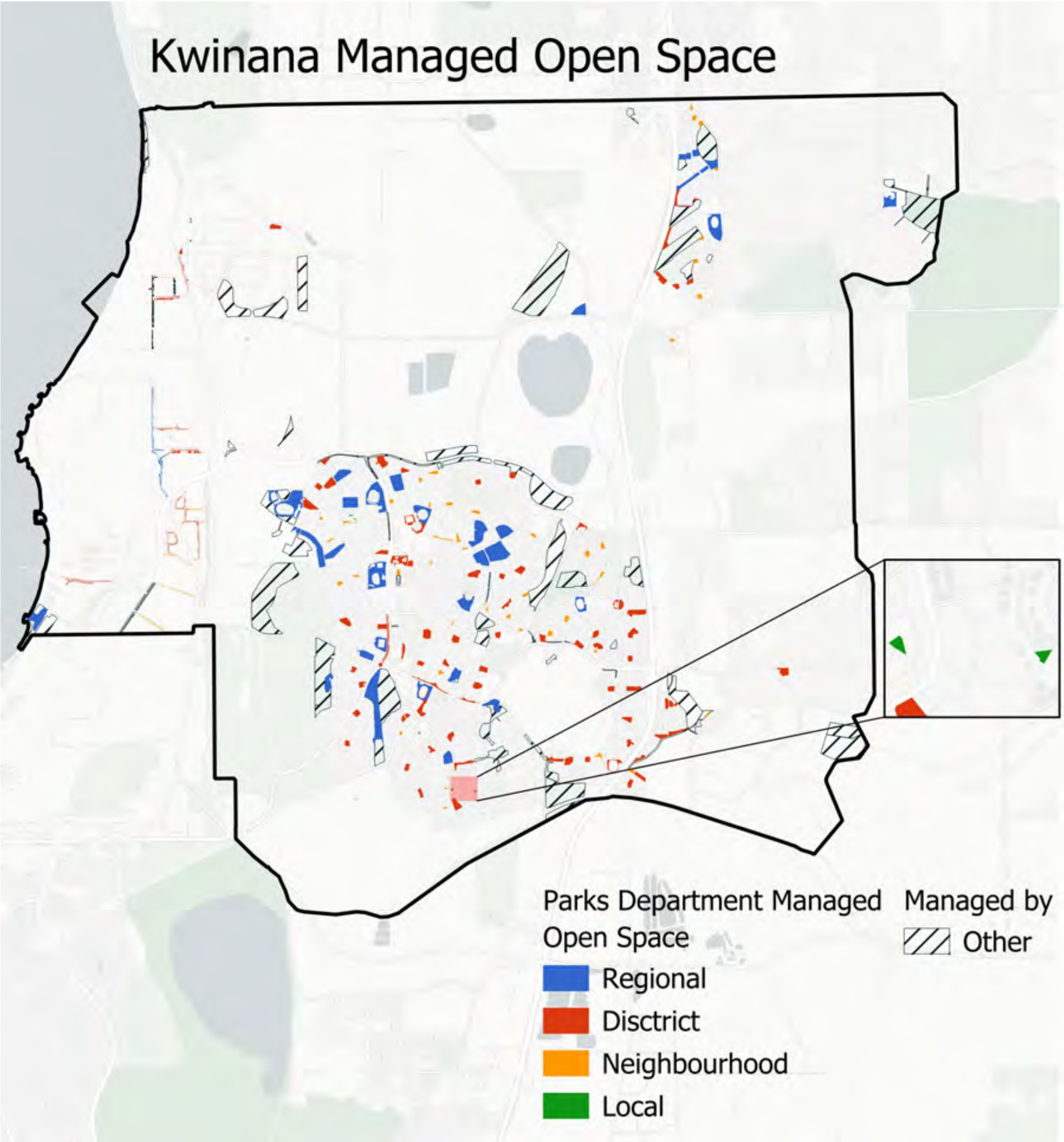


Figure 15: Kwinana Managed Open Space, separated into open space managed by the Parks department (further categorized into Regional, District, Neighbourhood and Local), and open space managed by other departments.

Figure 16: Proportional canopy cover of each category of Parks Department managed Open Space (left), and contribution of each category of Parks Department managed Open Space to overall canopy cover (right).

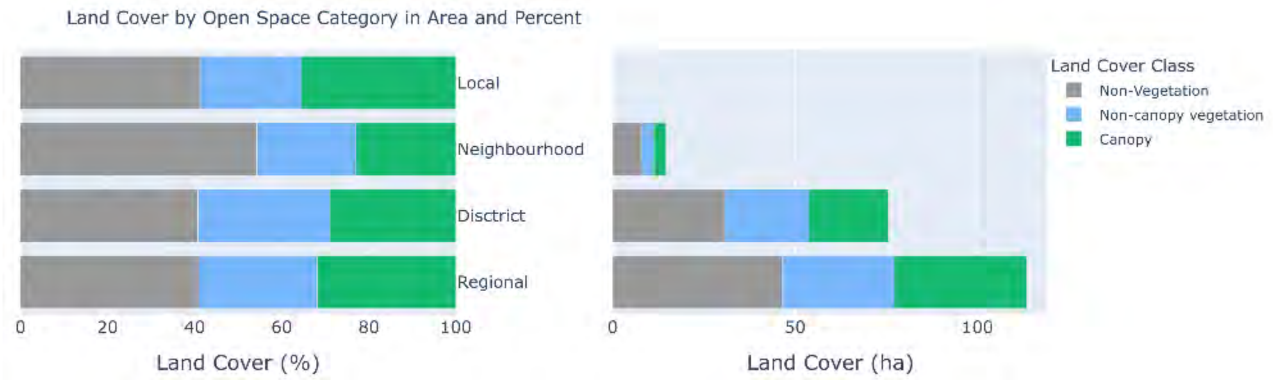


Figure 17: Land cover classification proportion (%) (left) and hectare coverage (right) of the Parks Department managed Open Space in City of Kwinana.

2.5.2.4 Residential Development

Most residential land in Kwinana is designated a Residential Design code (R-code) (Figure 18). R-codes are legislated planning and design provisions for residential land in Western Australia and include specifications that relate to canopy coverage. Section 4.1.1 Assessment of Impact of Infill Subdivision and Section 5 Canopy Cover and Urban Forest Targets both utilise canopy cover statistics derived from the land classified under the existing R-codes. R5, which is the largest lot size, had the highest proportional canopy cover (39.2%, Figure 19). However, R12.5/20 is the most common R-code in the City, and while the proportional canopy cover in this R-code was below average (14.3%), it contributed the most canopy cover to the overall canopy cover for R-codes, due to its large area (Figure 20).

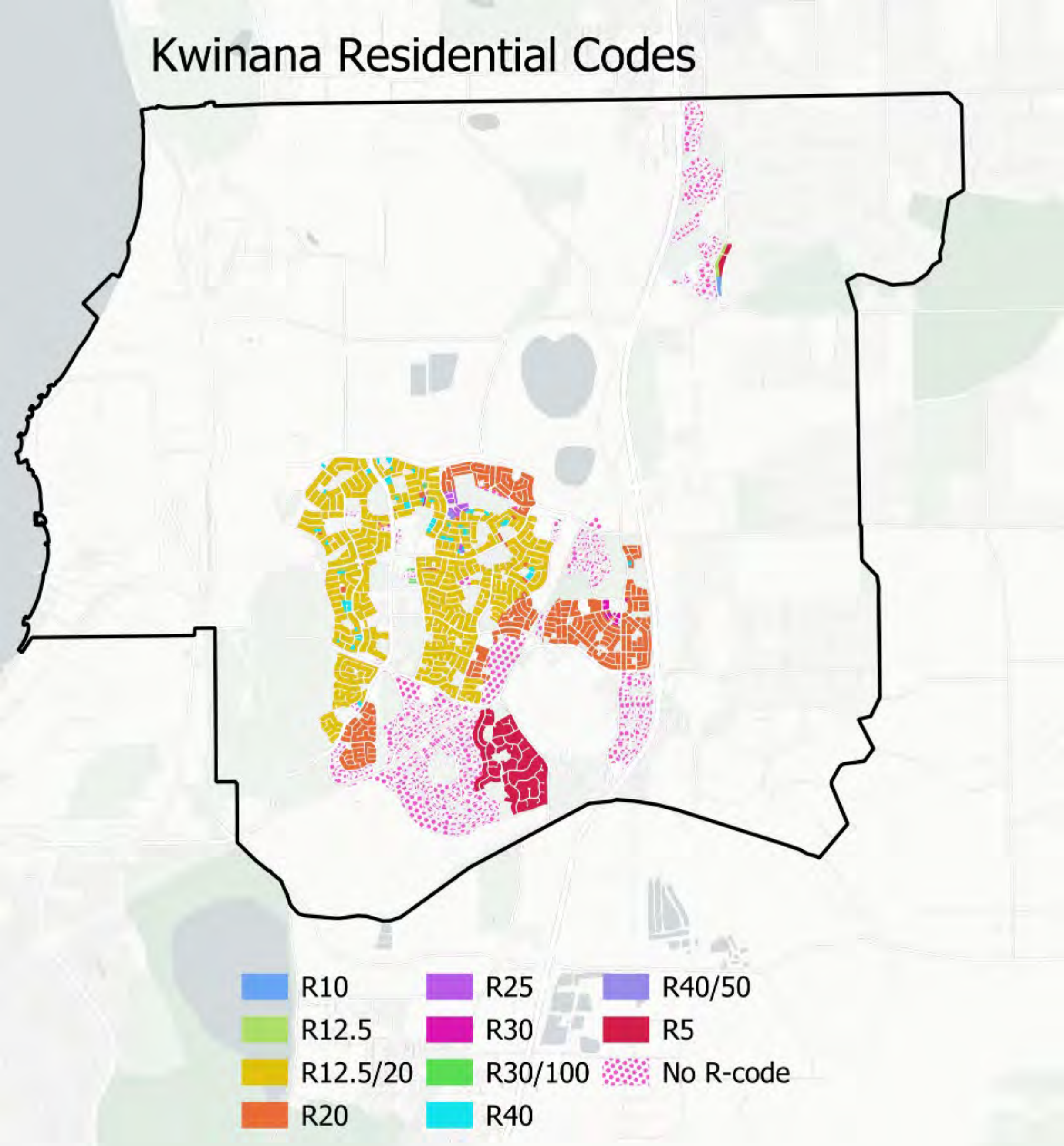


Figure 18: Residential land categorized by Residential Design codes (R-codes) used to determine canopy cover (excluding no R-code).

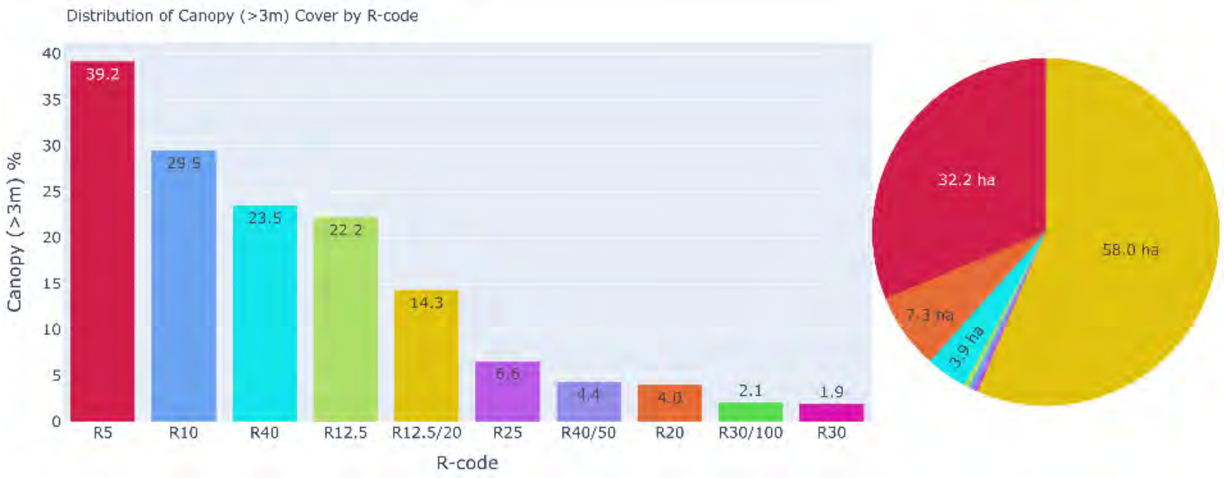


Figure 19: Proportional canopy cover of each R-code (left), and contribution of each R-code to overall canopy cover (right).

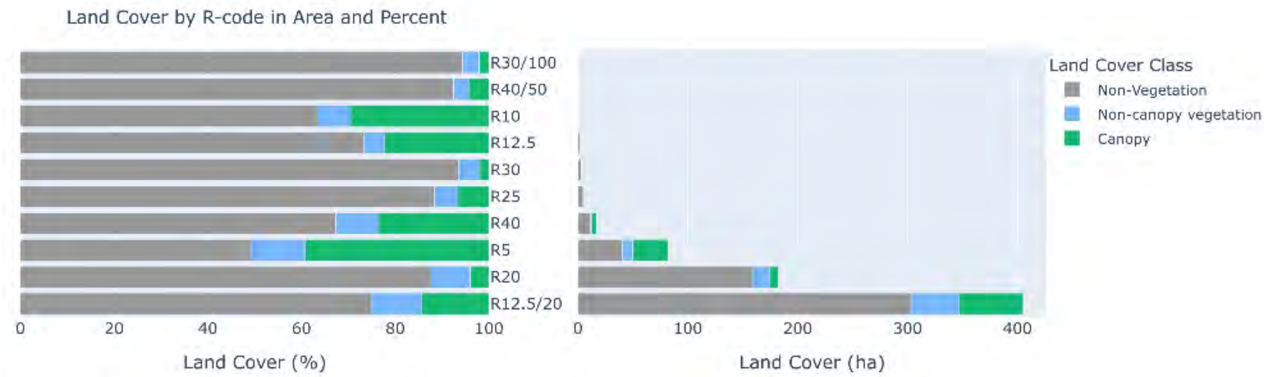


Figure 20: Land cover classification proportion (%) (left) and hectare coverage (right) of the R-codes in City of Kwinana.

2.5.3 Available Planting Space

Analysis of available planting space (APS) was undertaken to identify land available for planting trees and increasing canopy cover. APS was determined as areas identified as grass or bare earth in the 2023 aerial imagery, limited by numerous factors, including the area shape and size, assets such as powerlines and lighting poles, distance to road intersections, and sporting fields.

The resulting APS dataset identified many verges, median strips and other road spaces with no canopy cover, and the space available for one or more trees (Figure 21). This APS data was used to calculate canopy cover targets for Streetscapes in Section 5.

Over the next 25 years and beyond, there will be opportunities for the existing overhead distribution power network to be undergrounded. As and when this occurs, additional opportunities will be created for the establishment of tree canopy. As these projects will be in older suburbs, with wider road reserve and larger house setbacks, any underground power project should be seen as an opportunity to plant trees with large canopies, and to allow existing large trees, restricted by the powerlines, to grow to full canopy size.

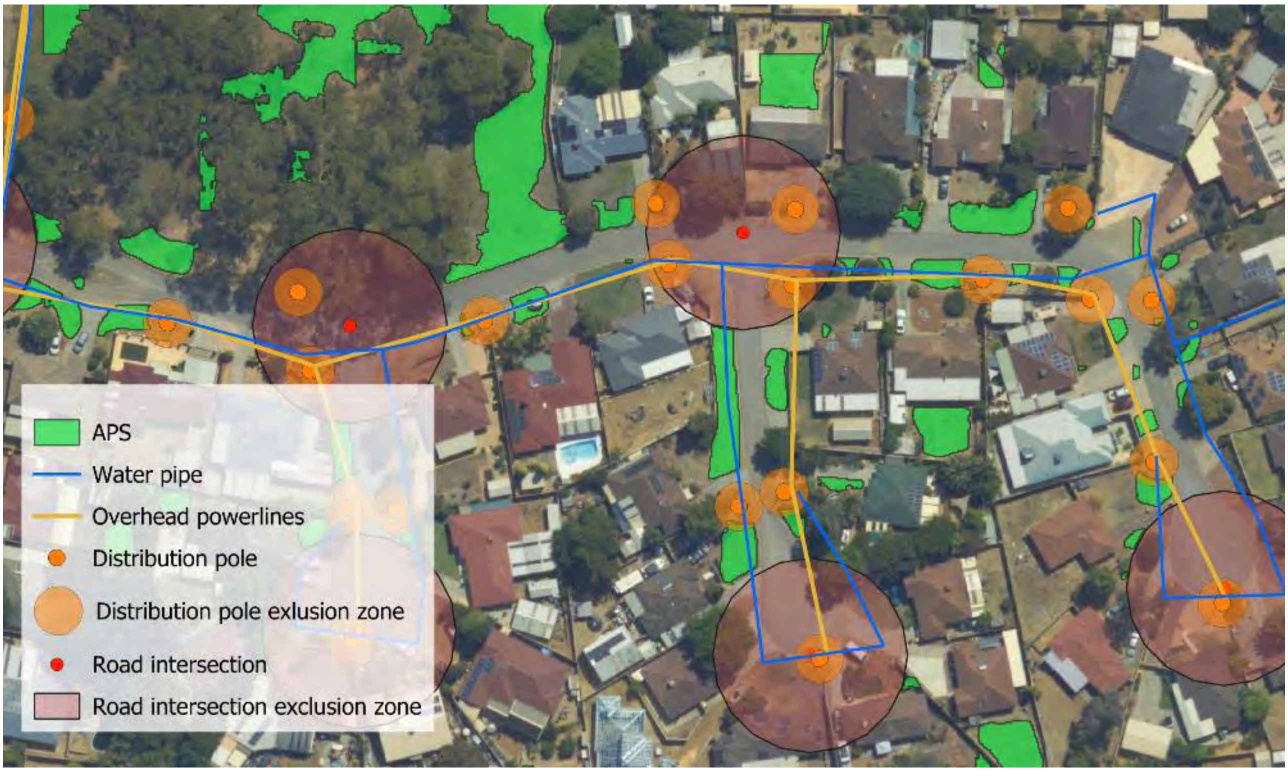


Figure 21: Available Planting Space (APS) as well as limiting factors used to determine areas of APS.

2.5.4 Urban Heat Island Analysis

The negative effects of global warming on human health, wellbeing and productivity are well known and discussed in detail in Section 4. These effects are felt most acutely in cities rather than rural areas, due to the occurrence of the urban heat island effect (UHIE). Therefore, addressing the UHIE has been identified as a key strategy to mitigate the effects of climate change on human health (Janowiak 2021).

ArborCam land surface temperature data was acquired concurrently with canopy cover data on 23rd March 2023 (Figure 22). Identifying hot and cool spots was conducted through spatial autocorrelation (clustering). Pixels with a p-value of 0.001 were considered statistically significant cool spots or hot spots. To be statistically significant, the hot/cool spot needed to consist of a feature with a high or low land surface temperature value and be surrounded by pixels with high or low values.

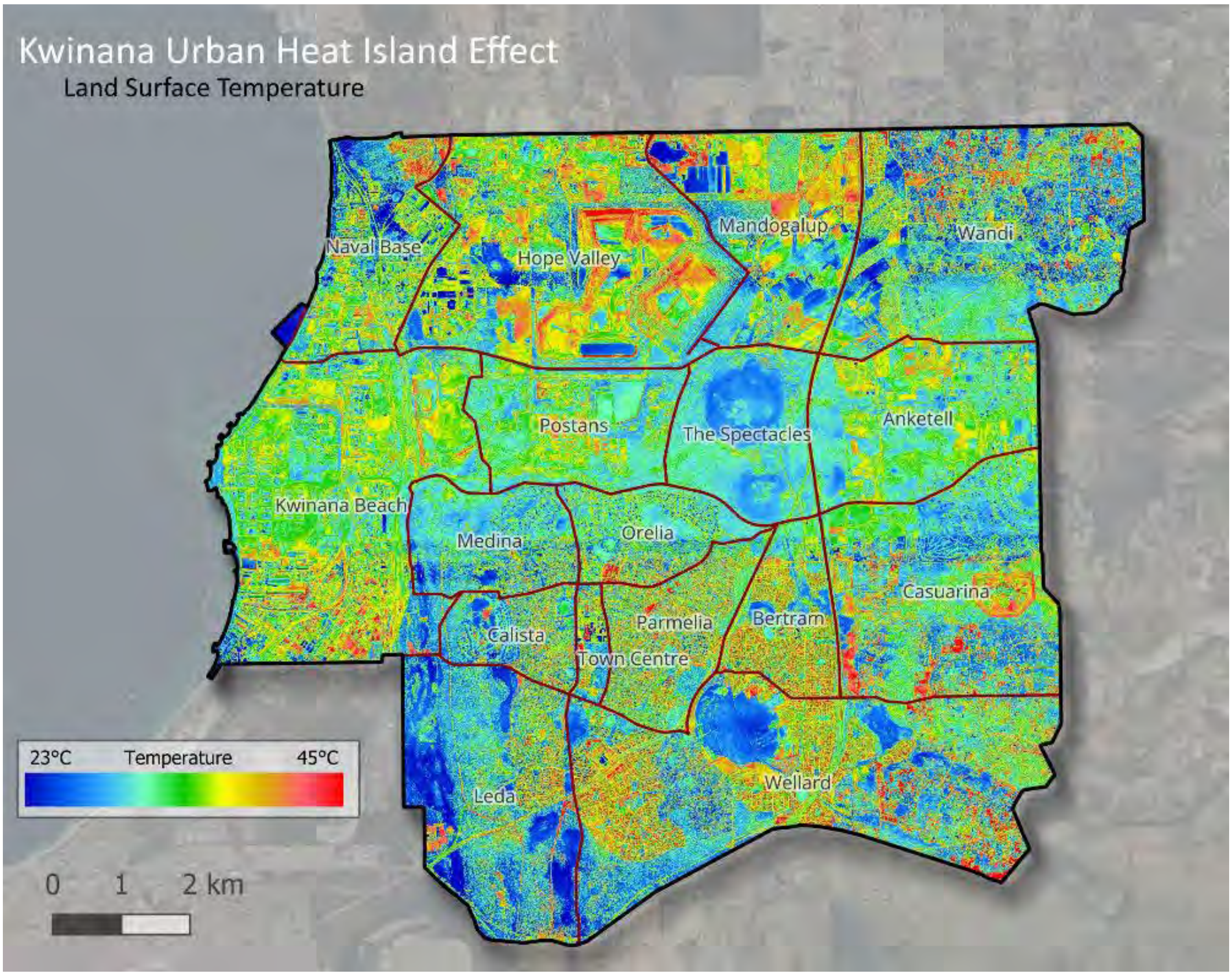


Figure 22: Land surface temperature data used to determine hot and cool spots.

2.5.4.1 Hot and Cool Spots

Hot spots throughout the City are presented below. Hot spots were primarily land with very little vegetation cover and with significant impervious surfaces, such as industrial areas, residential areas, the Casuarina Prison, or land cleared for development purposes. This cleared land corresponds to Kwinana's future growth areas and is zoned for residential development. This land currently has some of the highest land surface temperatures in the City, and opportunity exists to improve this during development with proper planning.

Similarly, cool spots identified in the land surface temperature dataset and are also presented. Cool spots were mostly areas of dense vegetation, including remnant vegetation, wetlands, parks and older neighbourhoods with established tree cover. The surface temperatures were generally 10°C lower in these areas when compared to the hotspots throughout the City.

Hope Valley Industrial Area

41°C

Large areas of cleared land and bare earth used for industrial purposes absorb and retain heat.

Mandogalup Greenfield Development

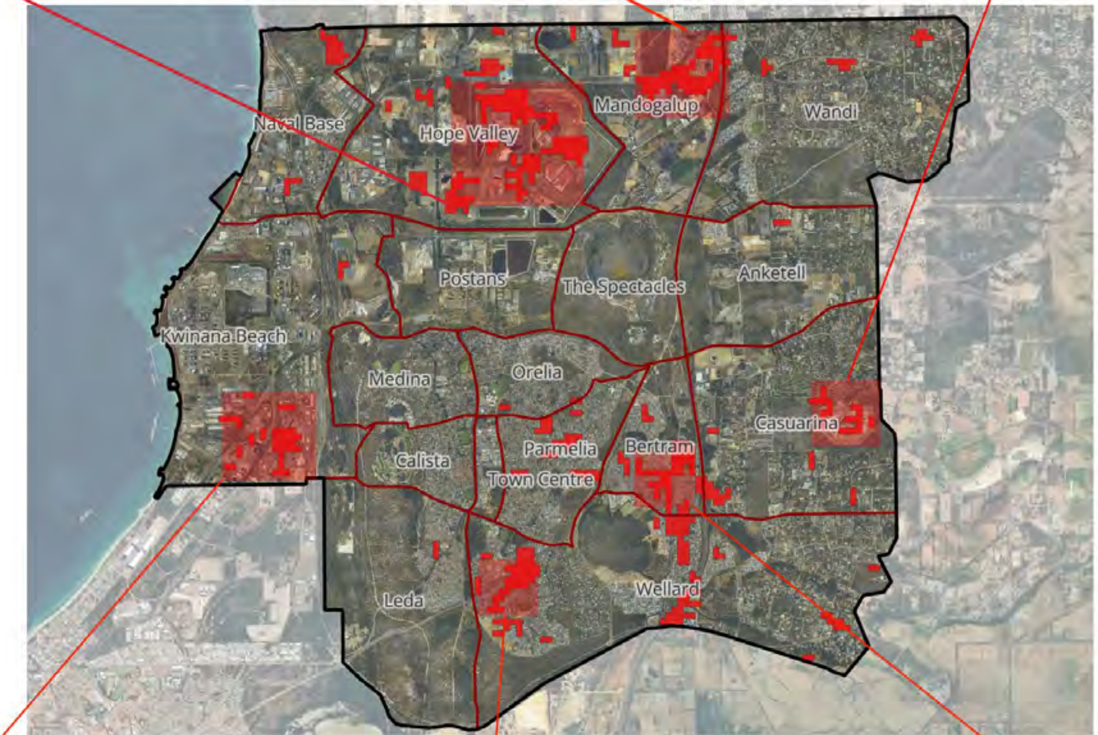
40°C

At the time of acquisition, the land was largely cleared of vegetation for development purposes.

Casuarina Prison

40°C

The Prison grounds is largely void of vegetation, and the majority of land is bare earth that absorbs and retains heat.



Kwinana Industrial Area

39°C

Primarily asphalt and concrete surfaces used for industrial purposes, with sparse vegetation throughout.

Wellard Neighbourhood

39°C

Recently developed high density neighbourhood with minimal green space and few established street trees.

Bertram Neighbourhood

40°C

Recently developed neighbourhood with minimal green space and few established street trees.

<u>The Spectacles Wetland</u>

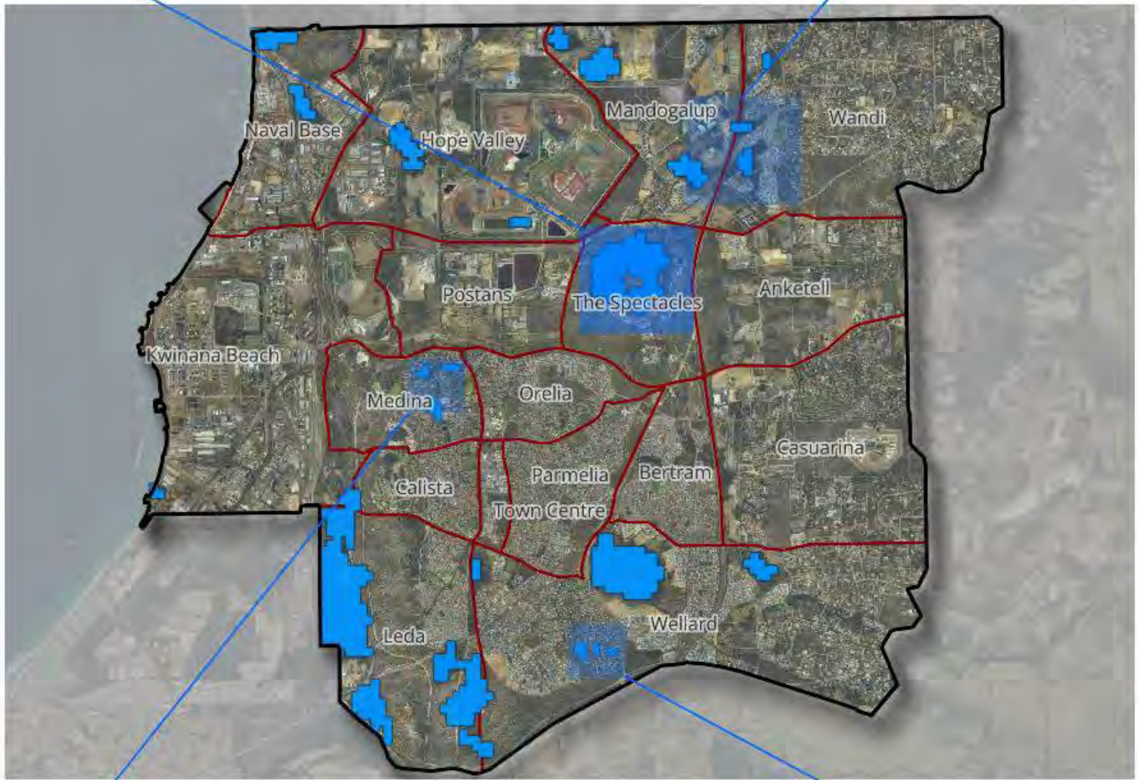
30°C

Wetland area with dense remnant vegetation. Dense vegetation and water bodies stay cool in hot weather.

<u>Remnant Vegetation</u>

29°C

Areas of remnant vegetation are significant cool islands adjacent



<u>Established Medina Neighbourhood</u>

31°C

Established neighbourhood in Medina with dense vegetation cover and large areas of well-canopied open space.

<u>Established Wellard Neighbourhood</u>

30°C

Established neighbourhood in Wellard with significant healthy canopy cover in public and private land.

2.5.4.2 Tree Canopy and Urban Heat

The relationship between urban land surface temperature and tree canopy cover is explored using a hexagonal grid which summarises the canopy cover dataset (Figure 23) and the land surface temperature dataset (Figure 24), using a standard 8.5 ha hexagonal area. A distinct linear relationship between mean tree cover and land surface temperature is present in the data.

Figure 25 shows that within Kwinana, a 10% increase in canopy cover is associated with a 1.5°C drop in surface temperature during heatwave conditions. These results show the broad, landscape-scale effects and do not capture local, small-scale, variations in air temperatures associated with canopy. For example, standing directly under the shade of a tree is likely to provide a much more pronounced cooling effect than the broad landscape scale effects observed in Figure 23 and Figure 24.

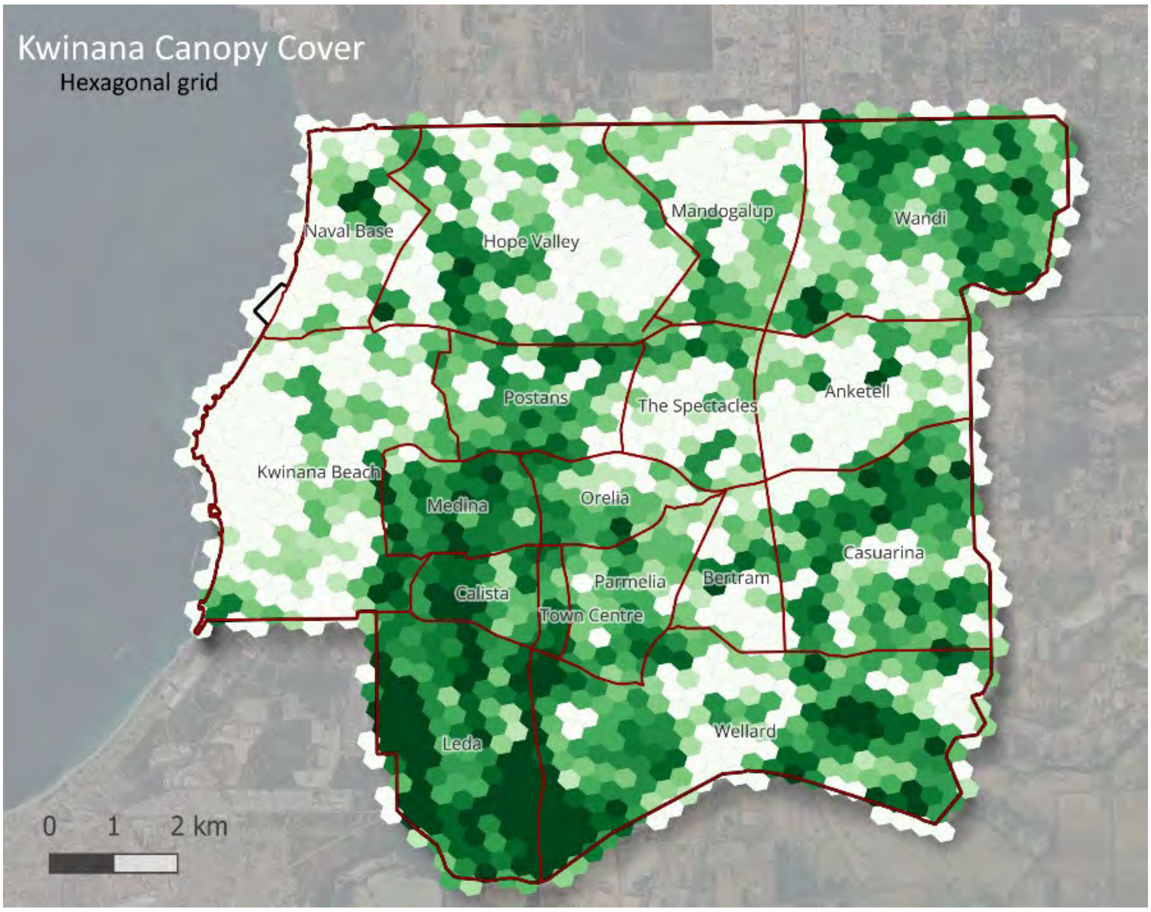


Figure 23: Canopy cover data summarized by hexagonal grids, illustrating a clustering effect, generally opposite of the land surface temperature data.

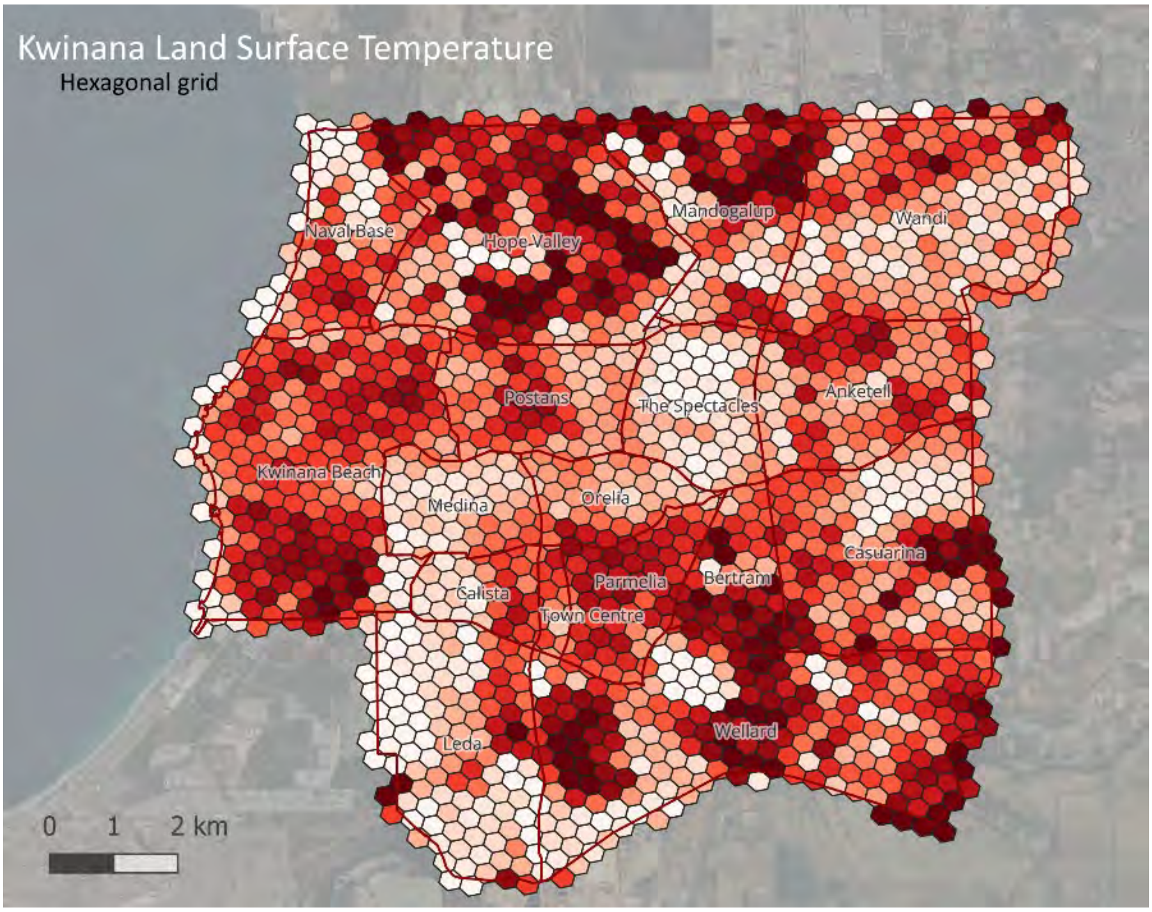


Figure 24: Land surface temperature data summarized by hexagonal grids, illustrating a clustering effect, generally opposite of the canopy cover data.

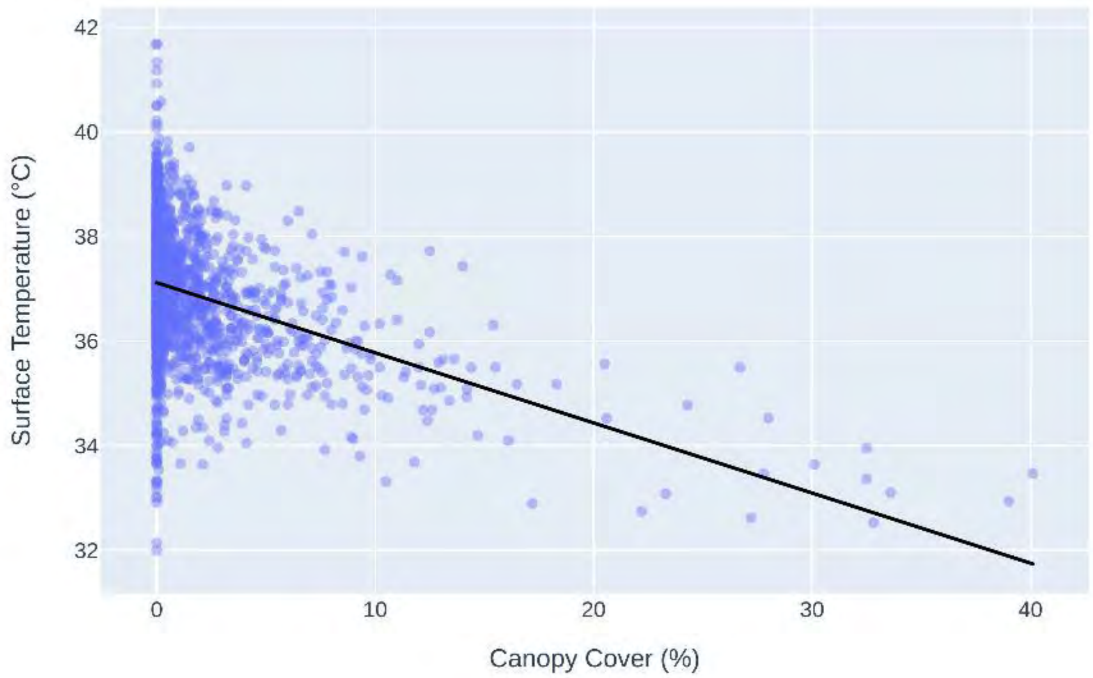


Figure 25: Scatter-plot showing the relationship between tree canopy cover and land surface temperature.

3 Challenges

3.1 Development

Over the next 10-15 years it is estimated approximately 15,000 houses and 30,000 people will be added to the City. Most development occurring in Kwinana is greenfield. Greenfield development refers to the construction of new buildings and infrastructure on previously undeveloped land. This land, often located on the outskirts of the City or in rural areas, has not been used for urban development before and typically consists of open fields, farmland, or other natural landscapes. When greenfield development occurs, it often involves clearing existing vegetation, including trees, to make way for new construction (Figure 26).

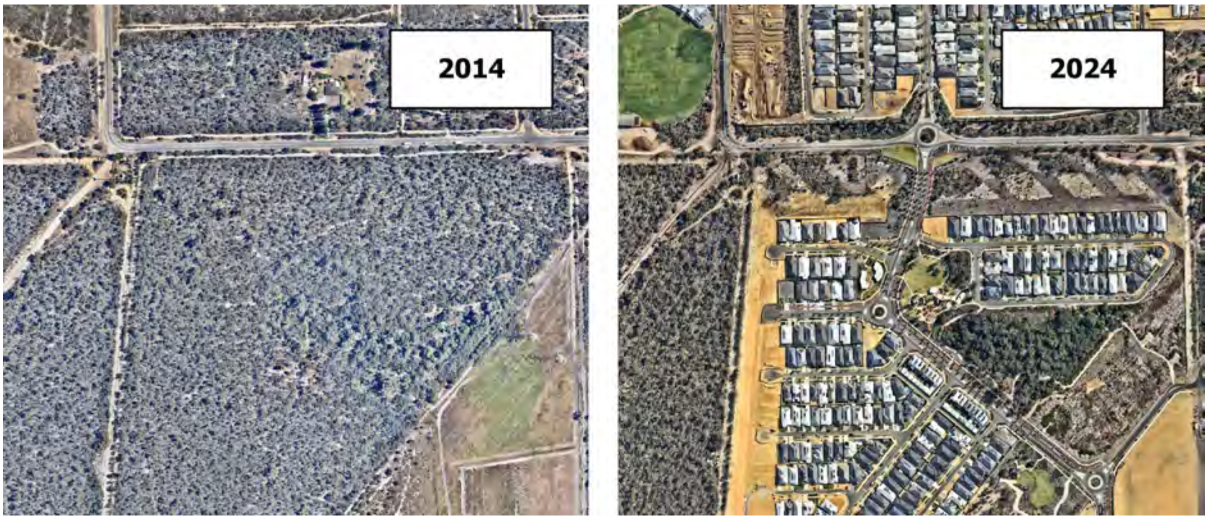


Figure 26: Greenfield development resulting in loss of canopy cover in Mandogalup. (Imagery source: Nearmap.com)

Land classified as Development currently has 13.3% canopy cover (170 ha). Considering this land will be used for greenfield development, under current development specifications, any vegetation will be cleared before development and resulting canopy cover will be due to developer plantings. The canopy cover targets in Section 5 take this into consideration, and set aspirational targets for canopy cover, based on projected land use.

Infill subdivision is less common in the City; however, it is possible that it will become more common in the future as the population expands. Infill subdivision refers to the process of dividing a larger parcel of land within an already developed urban area into smaller lots or plots for new development (Figure 27). Infill subdivision aims to increase urban density, make efficient use of existing infrastructure and services, and contribute to the revitalisation of established communities. Infill subdivision increases urban density and often results in the removal of existing trees to ease construction, with a resultant reduction in available space and deep soil for sustaining large tree canopy. Some LGA’s with higher dwelling density, such as the City of Canning, Nedlands, South Perth and Town of Cambridge, are showing leadership in their attempts to protect trees on private property by adopting changes to Local Planning Policy and proposing amendments to Local Planning Schemes. Lessons learnt by these councils may be useful for the City of Kwinana.

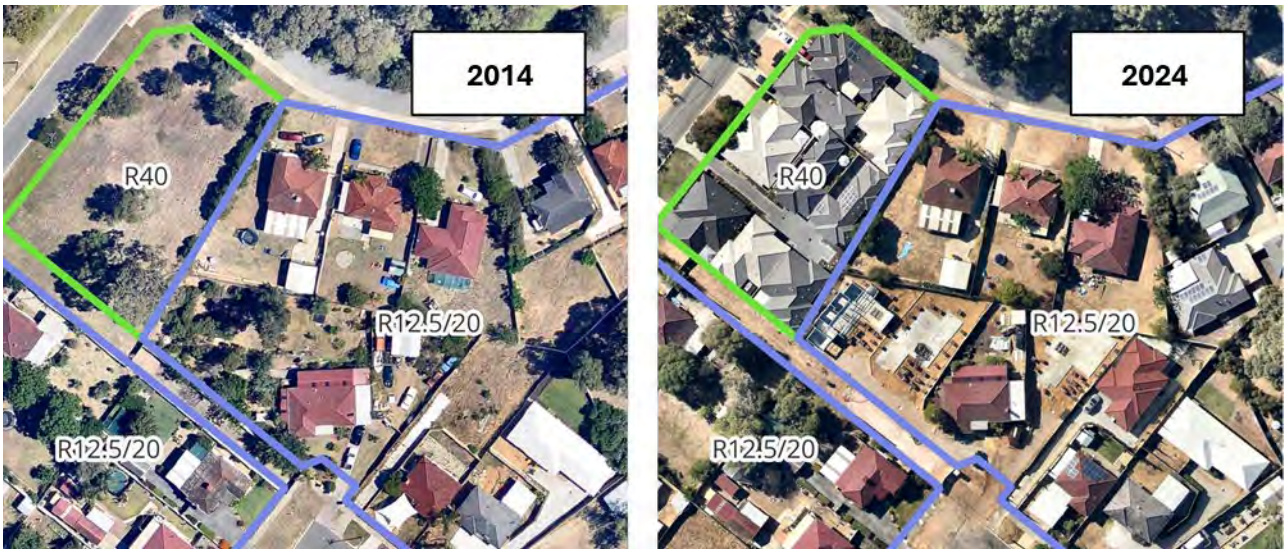


Figure 27: Infill development resulting in loss of canopy cover in Medina. The most-recent Residential Design Codes are overlaid on the imagery. (Imagery source: Nearmap.com)

3.1.1 Assessment of Impact of Infill Subdivision

The potential impacts of infill subdivision on canopy cover throughout existing residential land in Kwinana has been modelled. The analysis was conducted on residential lots according to their Residential Code (R-code) (Figure 28) (see State Planning Policy (SPP) 7.3 – Residential Design Codes Volume 1 and 2 for specifications). A detailed method of the analysis is provided in Appendix B.

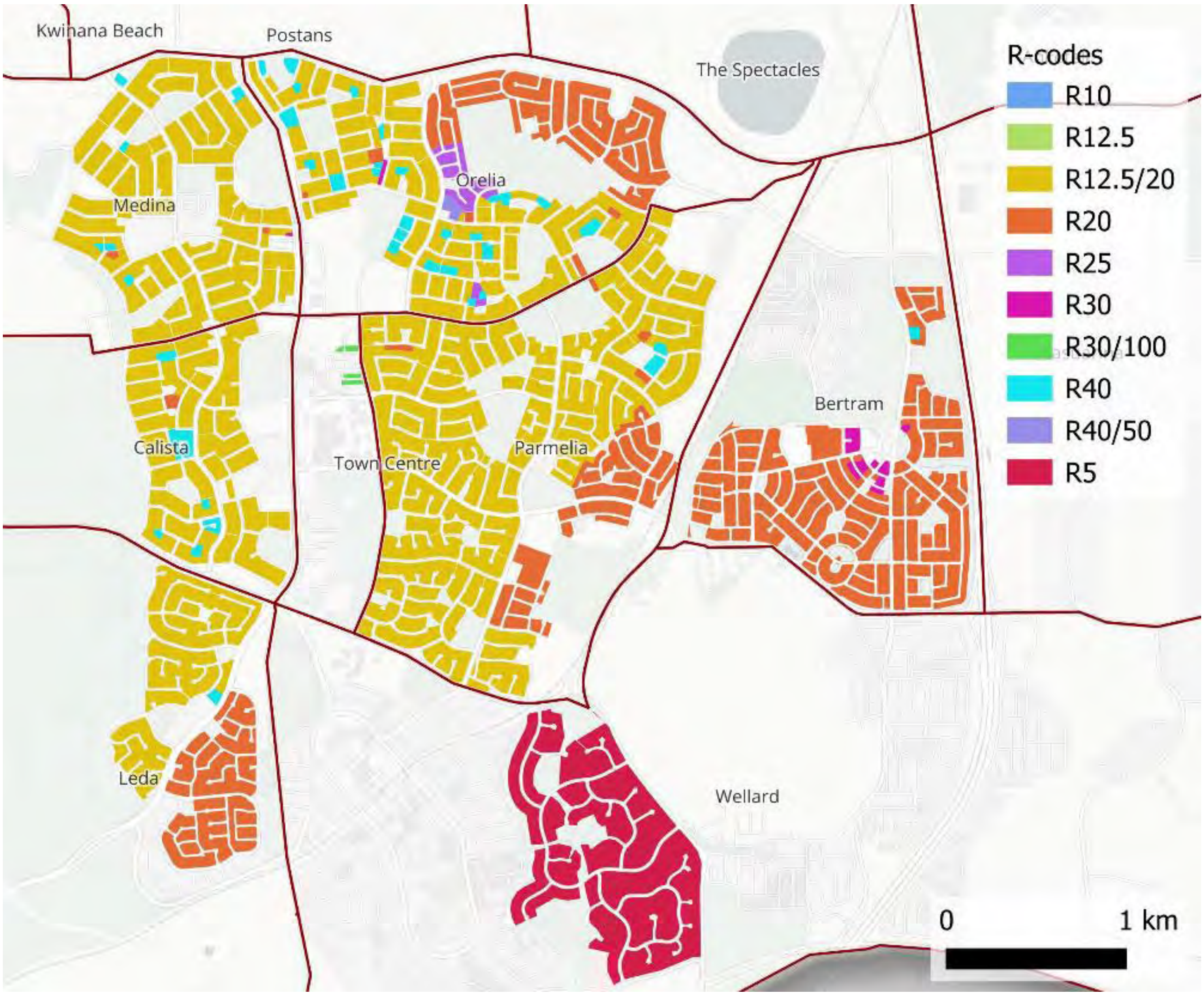


Figure 28: Residential land categorised by R-code (source: Local Planning Scheme - R Codes (DPLH-070)).

A map of the cadastral lots with and without development potential is provided in Figure 29 and the total number of lots in each category presented in Figure 30.

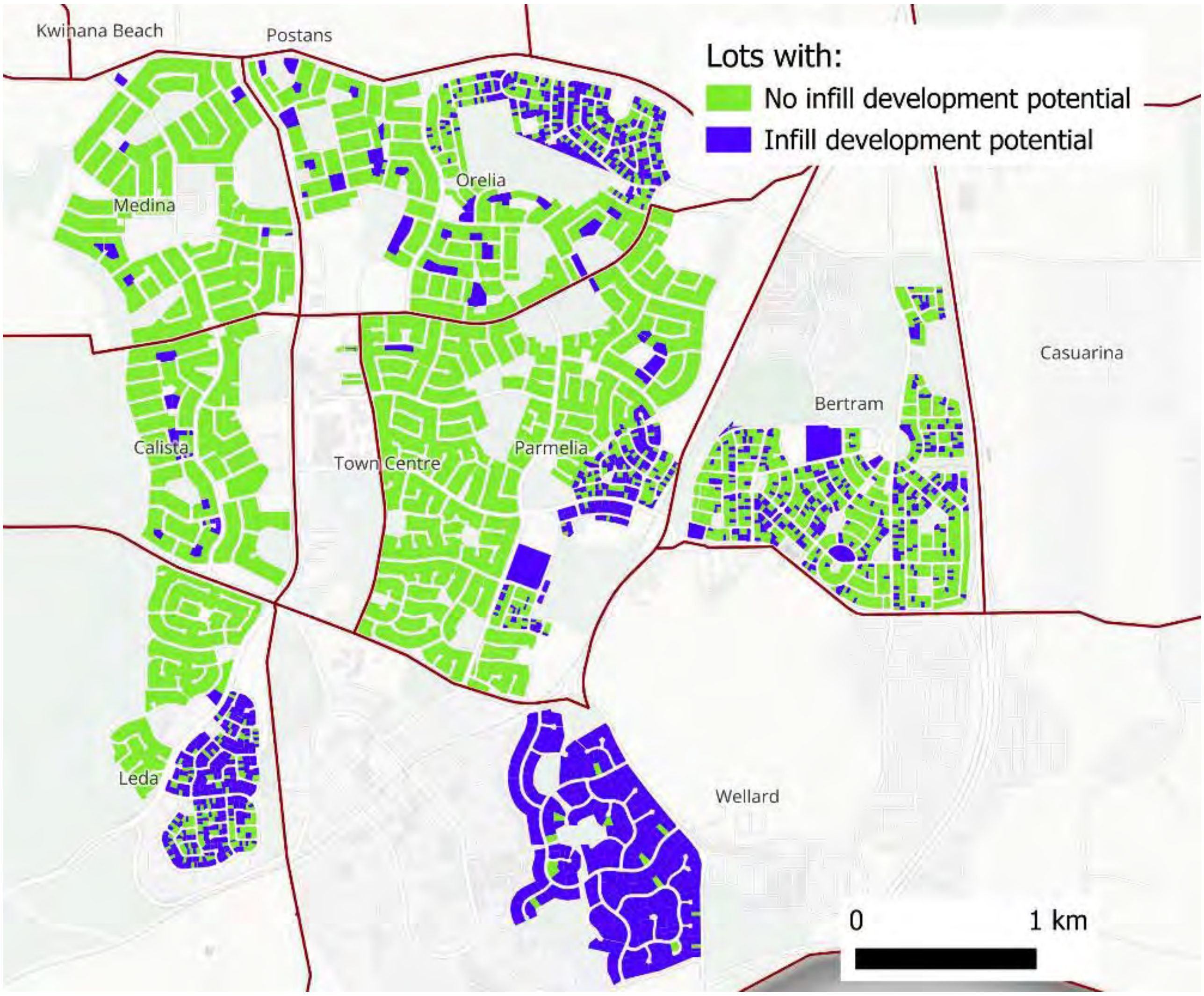


Figure 29: Each lot is colourised by infill development potential. Under the current residential design code specifications, purple lots have infill development potential and could undergo significant canopy loss, while green plots are considered fully developed and unlikely to lose canopy.

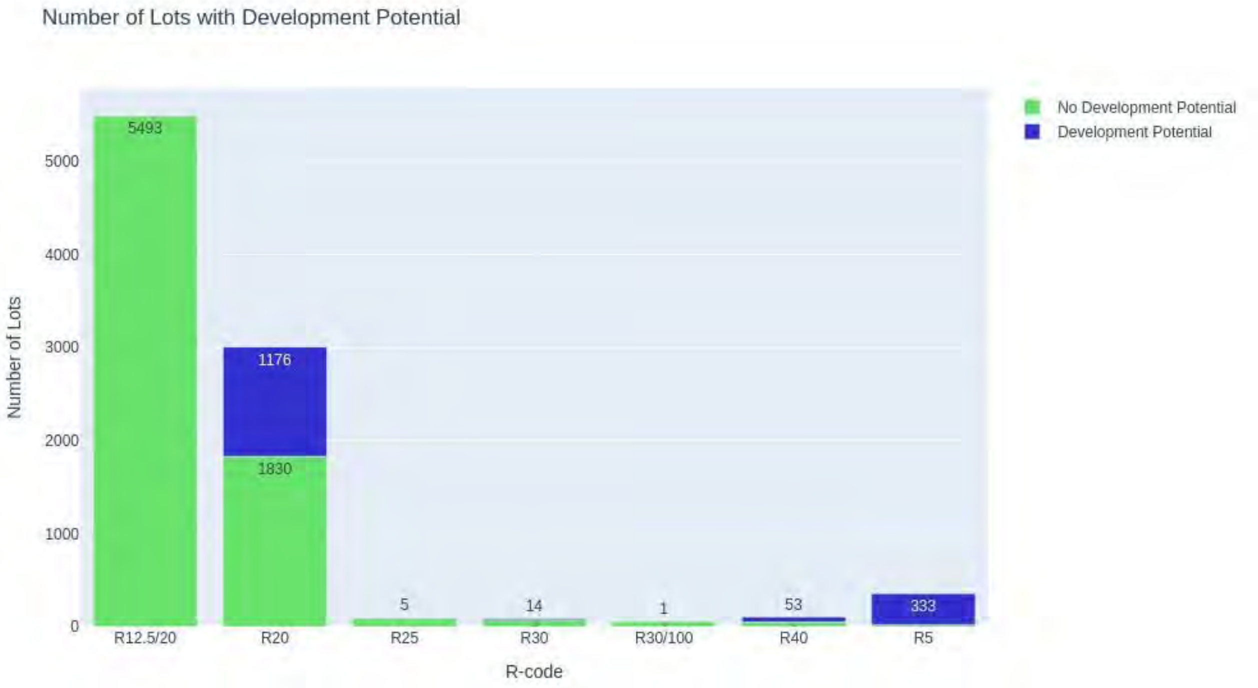


Figure 30: Number of lots with and without infill development potential, categorised by R-Code.

If each residential lot in the City of Kwinana with subdivision potential is developed to its capacity, this will result in a **decrease in canopy cover on residential land under the current R-codes from 14.7% to 13.3%.** This is a loss of approximately 10.5 ha of canopy, equivalent to over 2000 trees (medium sized tree with 50m^2 crown area) and a 9.5% loss in the existing canopy. Most of this loss will occur on land zoned as R20 (4.3 ha of canopy cover), as well as land zoned R40 (3.4 ha of canopy cover) (Figure 30). Most of the residential land in this analysis is zoned R12.5/R20 (Figure 31). Under the current residential design codes, these lots will not undergo infill subdivision and therefore are not likely to lose canopy cover. There is also the potential for further canopy cover loss around the City centres, as the City progresses it's Precinct Structure Plans resulting in potential upcoding.

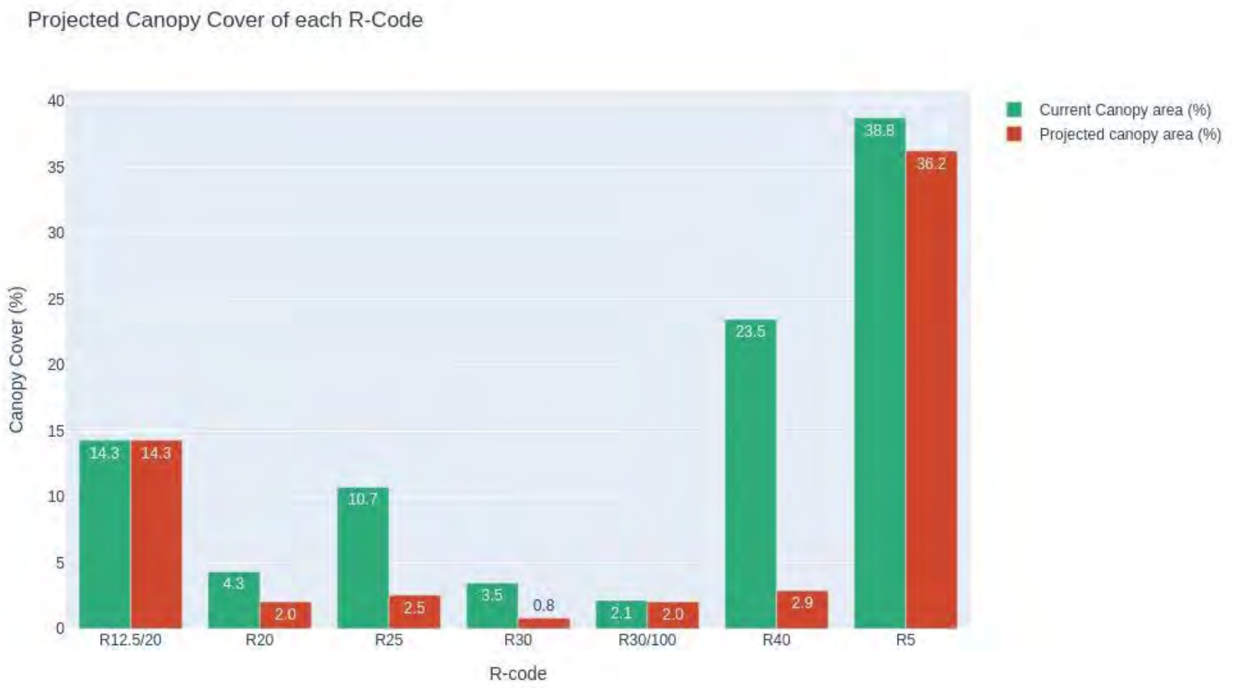


Figure 31: Current and projected canopy cover (%) for lots in each R-Code.

It is important to consider the assumptions of this method of canopy cover projection. For example, it assumes that each lot considered fully developed (no development potential) already has its maximum established canopy. However, there may have been significant recent development of R25 lots which have not yet had the opportunity to establish their canopy cover. Therefore, the projected loss of canopy cover may be an overestimation. In addition, this method assumes every lot will be developed, which is unlikely to be the case. This outcome could be considered the 'worst case scenario'. It also does not provide a time-line – the rate of development is unknown, and this outcome is the 'final' outcome. Finally, the City is currently considering options to promote/protect the existing tree canopy on private and public land, which might mean that past performance in protecting trees during infill is not indicative of future protections.

3.1.2 Poor planting practice and maintenance in new developments

Developers are responsible for establishing trees in new development areas, and while developers should give due regard to the City's tree policies and strategies, they are not statutorily required to do so unless as a condition of subdivision. . New trees planted by developers as part of new subdivisions are often poor quality and planted during development, with subsequent decline, death or removal often occurring.. Post a two-year maintenance period and hand-over to the City for management an opportunity exists to adopt new technologies such as airborne remote sensing to geolocate new trees on verges to ensure compliance, and monitor their growth and health over time.

It is critical that Council ensures that developers only purchase and plant trees that conform to the Australian Standard AS 2303:2018 Tree Stock for landscape use and WALGA guidance for the purchase of tree stock. The hand selection of trees grown to AS 2303:2018 will improve the quality of the stock planted within new developments. Species selection will continue to be a critical factor for future resilience of the City's urban forest, particularly in a drying and warming climate, and with the introduction of new pathogens and pests (e.g. Polyphagous Shothole Borer). As such, a thorough review could be undertaken by qualified professionals to determine which species are most suitable, and a following assurance they are available from the WA nurseries, and to develop a Street Tree Master Plan which includes species suited to different regions within the City. Some of the City's planning policies (i.e. Local Planning Policy No. 1 Landscape Feature and Tree Retention) are nearly 10 years old and require review and amendment to improve the survival and longevity of urban trees during and post-development.

3.2 Policy shortfalls and protection of existing trees

The Urban Forest Strategy aims to protect, retain, and increase vegetation cover as part of the planning and development process. However, this will require introducing several mechanisms, such as environmental provisions in the City's *Draft Local Planning Strategy*, *Planning Scheme*, and relevant policies.

The planning legislation associated with the subdivision approvals process, determined by the Western Australian Planning Commission (WAPC), often prevents local governments from addressing key design issues affecting tree retention. Consequently, vegetation and trees are frequently removed during development to facilitate subdivision.

The City considers it a high priority to address urban planning issues associated with greenfield development to better retain existing remnant vegetation within new broad-acre developments ahead of the development front. The issues involved are complex and will require engagement with many stakeholders, including the development industry sector, Urban Development Institute of Australia (UDIA), WAPC, and WALGA. Bringing about change and improved outcomes will take considerable time, but the City considers this matter so important that engaging relevant stakeholders is a matter of the highest priority. There is a will and intent within the City to retain significant trees, however, the lack of protection and resources to ensure compliance, sadly means that many significant trees are removed. The current penalties for people caught causing damage to trees is very small (around $250), and linking decline or death of trees due to development is challenging. An opportunity exists for the utilization of technologies such as airborne remote sensing and forest pathology to assist with this (Figure 32). This data has recently received a national Parks and Leisure Australia award for the best use of technology for urban forest management.

Figure 32: Airborne ArborCam baseline image in 2023 (left), 2024 (centre) and the change in Vegetation Condition Index (right) showing where vegetation has been heavily pruned (red pixels) over a 12-month period.

3.2.1 Trees as assets

Trees are not currently managed as assets in the City of Kwinana, and there is not a tree inventory in place. There is no tree inventory in place and tree removal and maintenance tasks are not recorded in the asset or work order system. The numerous values that trees provide (see section 1.2.2) are not being formally recognised and therefore are not being appropriately managed and maintained. Assessing the value of tree assets motivates decision-makers to prioritize design plans that preserve and protect mature, healthy trees. The practice of valuing trees, using a range of methods including Helliwell, Melbourne, Thyler, and Burnley, is becoming increasingly common among Australian cities. Establishing a clear and reliable method for monetarily valuing trees is essential for making a compelling case for the preservation of the urban forest.

Kwinana should conduct a preliminary investigation into the various valuation methods used by different LGAs in Australia and select a preferred method. The City of Melbourne is recognized for having a strong valuation model (Arboriculture Australia & NZ Arboricultural Association 2022), which meets Minimum Industry Standards (MIS) and considers both the amenity and ecological values of trees. Placing a valuation on trees can facilitate the establishment of bonds or proportionate fines for damage or non-compliance during development.

There is also a strong desire for a Significant Tree Register within the City. It is important to define what is considered a 'Significant' tree, and once defined, ensure priority is given to the geolocation of these trees, assessment by a qualified arborist or equivalent, and the creation of a register. The inclusion of protection measures for significant trees on private land can only be successfully implemented if it is known what defines a significant tree, where they are located (if height or crown diameter is a key attribute), their baseline condition, and how they change over time. Technologies such as the airborne remote sensing can streamline the geolocation process (Figure 33), and facilitate compliance through change detection methods (Figure 32).

Figure 33: Airborne ArborCam image showing vegetation >15m in height as green pixels. Most of these are located in the Public Open Space (source: ArborCarbon).

3.3 Pests, diseases, water stress and other impacting factors

Manion (1981) identified the urban environment as a predisposing factor contributing to the premature decline of trees and forests, along with age and species. These factors can be categorized into abiotic (e.g., water stress, heat stress, or airborne pollution) and biotic such as pests and diseases (e.g., Polyphagous shot-hole borer, Phytophthora Dieback, Myrtle Rust) (Barber et al. 2013).

The **Polyphagous shot-hole borer** (PSHB) *Euwallacea fornicatus*, a beetle native to southeast Asia, has a wide host range and poses a significant threat to amenity trees, native vegetation, and the horticulture industry. It has a symbiotic relationship with a *Fusarium* fungus that kills the vascular tissues in susceptible trees, leading to death and/or decline. Some of the established and dominant tree species throughout Kwinana are potential hosts of PSHB, such as the *Ficus* Avenue planting along Medina Avenue, and the loss of these trees due to PSHB will be significant. An eradication program is underway across 25 LGA's in Perth, with more than one million trees assessed and over 800 trees removed at the time of the development of this Strategy. The City has reviewed its tree planting list, as many of the species on this list are hosts of PSHB and is proposing greater diversity of species in new and upgraded POS, and alignment to the Department of Primary Industries and Regional Development's guidelines for detection and management.

Myrtle Rust is a serious disease that kills many plants belonging to the Myrtaceae family, including eucalypts, peppermints, paperbarks, and bottlebrushes. At the time of development of this strategy, it has been found in the north of WA, and if not eradicated, it could potentially spread to Perth over the coming years. The real impacts to Perth's urban forest are unknown, however, it has the potential to significantly impact not only trees throughout the urban forest, but also the supply of trees from nurseries.

With the increasing movement of people and commodities into Australia, it is highly likely that new pests and pathogens will be introduced, leading to the decline and death of urban trees, if not eradicated or managed. The City of Melbourne recently developed a georeferenced tree database with filtering by host, pest or pathogen, enabling spatial investigation of their risk profile across parks and gardens, and providing a mechanism to develop planting plans that will increase species diversity (ArborCarbon 2023). This model presents a great opportunity for the City of Kwinana to replicate the approach and lead the way in WA with the development of a customised model.

Considering the current and predicted changes to climate, water and heat stress cannot be underestimated as a driving factor of tree decline. These both impact tree health by the same mechanism, and are significant contributing factors to decline, as they can make trees more susceptible to pests and disease. However, severe heatwaves and periods of drought can also result in tree death independently of other factors of decline. At the time of this Strategy development, Perth has recorded its driest October to March rainfall in recorded history, with only 21.8mm of rainfall (Bureau of Meteorology, 2024). Temperatures have also been above average in 2024 compared to previous years. Mass collapse of large areas of native forest have been observed, as well as widespread death of urban trees of all size classes. This is widely considered among tree experts to be due to recent drought and heat stress.

3.4 Climate change and urban heat

Australia's climate is predicted to increase in temperature, with rainfall becoming less predictable and more variable, and severe weather events more common. Figure 34 illustrates how climate change may affect the south-west region of Western Australia, for two time periods (2030 and 2090) and for two emission scenarios (RCP4.5 and RCP8), compared to current climatic records (1986 – 2005). Representative concentration pathways (RCP) depict potential greenhouse gas and aerosol emission scenarios. RCP4.5 is considered a moderate scenario in which emissions peak around 2040 and then decline, while RCP8.5 is the highest baseline emissions scenario in which emissions continue to rise. Under a moderate scenario, the south-west region of WA is predicted to experience an average temperature increase of 0.8°C by 2030, and 1.7°C by 2090, while under the highest baseline emissions scenario, the region will experience an average temperature increase of 0.8°C by 2030, and 3.4°C by 2090.

Variable		Current (1986–2005)	2030 RCP4.5	2030 RCP8.5	2090 RCP4.5	2090 RCP8.5
Annual rainfall			-13 to 0% (minor difference between scenarios)		-22 to -1%	-36 to -2%
Extreme rainfall and drought			Under all emissions scenarios, the time spent in drought is projected to increase. The intensity of heavy rainfall events is also projected to increase with medium confidence.			
Average temperatures			+0.8 °C (0.5 to 0.9)	+0.8 °C (0.5 to 1.1)	+1.7 °C (1.2 to 2.0)	+3.4 °C (2.6 to 4.0)
Frequency of hot days in Perth	**Days over 35 °C**	28 days	36 days		43 days	63 days
	Days over 40 °C	4 days	6.7 days		9.7 days	20 days
Fire weather (average number of days with a 'severe' fire danger rating)		4.2 days	5 days (19% ↑)	4.7 days (12% ↑)	5.3 days (26% ↑)	6.9 days (64% ↑)
Sea level rise			+0.07 to 0.17 m (minor difference between scenarios)		+0.28 to 0.65 m	+0.39 to 0.85 m

Figure 34: Projected climate change indicators for the South-west region of Western Australia. Image source Department of Water and Environmental Regulation (2021).

The Urban Heat Island Effect (UHIE) is a global issue, with cities consistently having higher temperatures than their rural surroundings. Additionally, within a city, the UHIE operates at a smaller scale, with some areas having higher temperatures than others due to limited vegetation coverage (Figure 35).

The steadily increasing warming trends associated with climate change are intensifying already higher temperatures in heat island areas. This is expected to worsen in the future as urban areas increase and vegetation decreases.

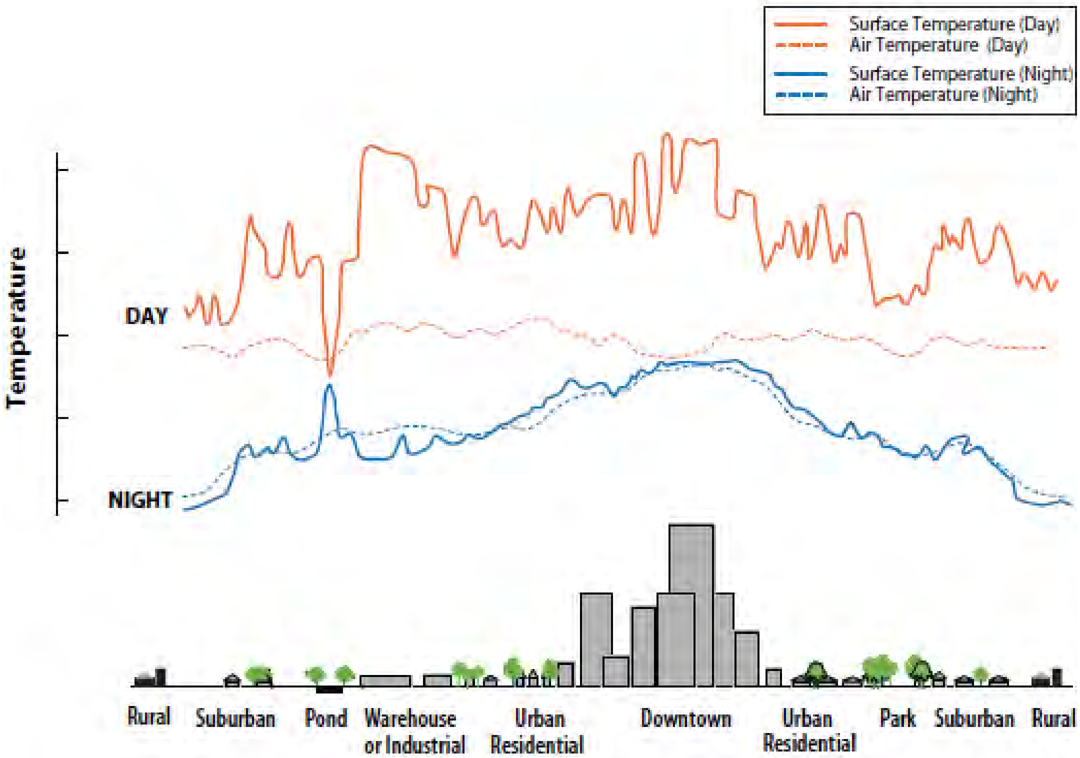


Figure 35: Schematic representation of changes in air temperature in relation to surface characteristics (EPA 2014).

The UHIE is a major concern during heatwaves, particularly for vulnerable populations. Heatwaves are already a leading cause of human death in Australia (Borchers Arriagada *et al.* 2020). To minimise the impact of the UHIE and reduce heat-related fatalities, it is essential to enhance the urban forest, particularly in areas with low canopy cover.

The UHIE also impacts the quality of life for residents by making outdoor activities less comfortable due to higher temperatures and hot spots in the city. This exacerbates health problems and the costs of cooling buildings.

The UHIE has significant environmental consequences in the long-term. For example, consumption of energy will be expected to increase, resulting in water resources becoming scarcer; this will place added stress on remaining green spaces, street trees and native vegetation. Remnant vegetation is generally more resilient to the UHIE, but it is not unaffected and can struggle to survive and remain healthy at increasingly extreme temperatures and under water stress, both of which are exacerbated by the UHIE. This has been observed across Perth during the 2023/24 summer. The maintenance costs of infrastructure will also increase because of heat exposure degradation.

Trees, parks, gardens and conservation areas all play a role in reducing the UHIE, with trees being particularly effective in lowering surface temperatures (Loughnan *et al.* 2013). Water also has a cooling effect on urban areas through the surface cooling effect of waterways and proper irrigation of vegetation.

To address the impacts of urban heat, Kwinana aims to maintain a diverse and well-connected urban forest across land use types, guided by its Urban Forest Strategy. Trees are long-lived assets. As trees planted today will form the landscapes of the future, it is important to select tree species that will be resilient to climate change.

Impacts of climate change on the urban forest could include:

- Increased likelihood of water stress and tree mortality due to reduced average rainfall. Existing trees may require regular, long-term irrigation, which would have significant resource implications for Kwinana.
- Leaf burn and canopy dieback caused by heat waves. These can also increase the imperviousness/water repellency of existing soils as they dry under increased and extended hot weather periods leading to decreasing water tables and increasing overland flow volumes (Li *et al.* 2019). Heat waves can also increase fire risk, frequency, intensity and spread.
- Canopy damage and/or total tree failure due to increased frequency and intensity of storms. Intense rainfall events and floods can destabilise root plates and increase soil salinity.
- Disruption to flower and fruit production and/or seed dispersal due to extreme weather events. This may not only affect the reproductive cycles of plant species but also the native fauna species whose survival depends on such food resources.
- Increased incidence of hot weather and heatwaves put stress on tree officers, arborists and tree maintenance workers, and negatively impacts the time available to undertake works.

3.5 Infrastructure and works

The urban public realm is a highly contested space, and finding room for trees can be challenging. Conflicts with infrastructure such as roads, buildings, footpaths and utilities are perhaps the most challenging issues. A significant factor in the premature decline of verge trees is the impact caused by the adjacent development of residential lots.

An opportunity exists to expand the protection of trees on verges, where practical, by establishing Structural Root Zones (SRZs) and Tree Protection Zones (TPZs) based on the *Australian Standard Protection of Trees on Development Sites AS 4970-2009*. The health of trees is not only dictated by the above-ground portion of trees, but also by the extensive below-ground root zone. The root zones of many trees may extend well beyond the drip zone of the crown, under cross-overs and into private property. Amendments to the *Local Planning Policy No. 2 – Streetscapes* could consider significant trees growing on adjacent verges that may be impacted by development.

Impacts from powerline clearance pruning to street trees can be observed throughout the City. This pruning significantly impacts the ability to establish good canopy cover and severely limits available tree-planting locations. The repeated pruning and resulting stress on trees can also predispose trees to infection by plant pathogens and attack from pests. Some locations where conflict occurs are exacerbated by poor tree species selection. Most new developments have underground power supply, but older, established neighbourhoods still have above-ground powerlines. The strategic installation of aerial bundled cables (ABC) would enable better tree planting outcomes and help preserve the existing canopy. . The benefits of undergrounding or bundling power lines are likely to far exceed the long-term negative impacts on the canopy and budget that come from inaction.

3.6 Lack of tree diversity

Kwinana's older suburbs have many 'avenue plantings', which are trees of the same species planted at around the same time, often coinciding with the development of a neighborhood. As such, the City has numerous trees of the same age approaching post-maturity, and localised low species diversity. This can result in sudden and significant loss of canopy if there is mass tree loss due to impacting factors, as well as an increase in expenses for tree removals and replacements. Kwinana strives to replace trees soon after they are removed or die, by identifying and removing trees that have reached the end of their useful life.

Low species diversity can reduce the resilience of urban forests to various factors that can trigger a decline in health. This is discussed in more detail in Section 5.1. It is impossible to determine the species profile of the City unless there is adequate and current data of the tree population that exists. It is therefore a high priority for the City to undertake a tree audit to gather the required data for further analysis. This will enable guidance for future planting to increase genetic diversity, but also facilitate some of the actions that have been listed to improve resilience to abiotic and biotic disorders.

3.7 Culture and Alignment

To achieve canopy targets, every department within the Council must support and recognize trees as essential assets. This includes all levels of the organization, from elected Council members and executives to managers, officers, and crews.

Tree protection and planting should be integrated into the City's capital and works programs. As urban space for trees decreases, all infrastructure projects should aim to incorporate and allocate funds for the following:

- innovative design ideas that provide increased soil volume, expanded canopy and root space for larger trees
- Water Sensitive Urban Design (WSUD) principles, structured soil, soil vaults, and permeable paving surfaces.

Staff within the City are passionate and open to new ideas around the protection and enhancement of tree cover throughout the City, however, it has been identified that additional resources are required to enable better tree retention and expansion of the City's urban forest. The City's aspirations are often hindered due to conflict between the greening ambitions of the City and the planning frameworks imposed by state government.

3.8 Social challenges

Negative attitudes towards trees were identified as a major obstacle to improving urban forest outcomes. These negative views can stem from fears about tree-related risks, cultural barriers, or aesthetic preferences. To address this issue, it was suggested that better education and engagement about the benefits of trees were essential. However, it's acknowledged that this is challenging to implement effectively and requires a carefully planned approach to achieve meaningful improvement.

Proactive maintenance has positive implications for tree management, as it ensures trees are regularly maintained and assessed, preventing reactive customer requests from becoming the primary maintenance approach. This proactive management, along with the visibility of the City's skilled maintenance crews, reassures residents that hazards are being managed and instills confidence that trees are well-maintained.

The City receives some pressure for native tree species to take precedence in new plantings throughout the City's urban forest. It is important to recognise and accept that both native and exotic large trees provide important environmental services and that they should be valued equally. In some cases, native species are suitable to be planted, and preference should be given to these considering their contribution to local native ecosystems. In other cases, the urban environment is totally different from a tree's natural environment, and a native tree is less suitable. Often, exotic trees are more suited to urban environments and can provide benefits such as increased solar access in winter months. A healthy, diverse, and resilient urban forest is one that includes both native and exotic species.

Some cities have successfully used several strategies to raise community awareness of the benefits of the urban forest. Part of this success was enabling residents access to urban forest data through a web portal (see melbourneurbanforestvisual.com.au). Allowing the community to engage with the available data that drives Councils decision-making processes encourages genuine interest and fosters transparency. The City of Melbourne has also initiated a Citizen Forester program where the City trains and empowers volunteers to carry out essential advocacy, monitoring and research related to improved urban forest outcomes, which in turn encourages participation in urban forest management and ownership. The City of Kwinana has the opportunity to develop similar programs and utilize the highly visual airborne ArborCam data showing the relationship between canopy cover and surface temperatures (Figure 36).

Figure 36: Airborne ArborCam image viewed through a web-portal showing canopy cover (green polygons) overlaid onto a baseline true colour orthomosaic (left), and surface temperatures colour-scaled from cooler temperatures (blue) through to hotter temperatures (red), with trees clearly demonstrating a strong cooling effect).

3.9 Tree maintenance and management

At present, only one person within the City, is tasked with tree planting and maintenance, with most of the work being undertaken by contractors. It is anticipated that increased resources and larger budgets will be required for maintenance and management in the future, for a range of reasons. These include scaling up of tree planting to help meet canopy cover targets, but also anticipated issues due to the impacts of development. Additional effort for maintenance in the early stages of establishment and growth, can greatly reduce the resources required in subsequent years as trees mature. For example, formative pruning during establishment can improve form and decrease the abundance of structural defects such as included unions. Timely removal of stakes can reduce rubbing and creation of wounds that lead to fungal infection, decay and stem failure. It is also common to see significant damage to the basal stem of trees through mowers and whipper-snippers, particularly where they are grown in turf. The repeated removal of the outer bark layer can lead to ringbarking of trees, or the wounds can open up points of entry for fungal pathogens (Figure 37). It is therefore obvious that the adequate allocation of funds to pro-active maintenance and management of trees, and adequate training of staff and contractors, particularly during establishment, will lead to substantial cost-savings in the future.

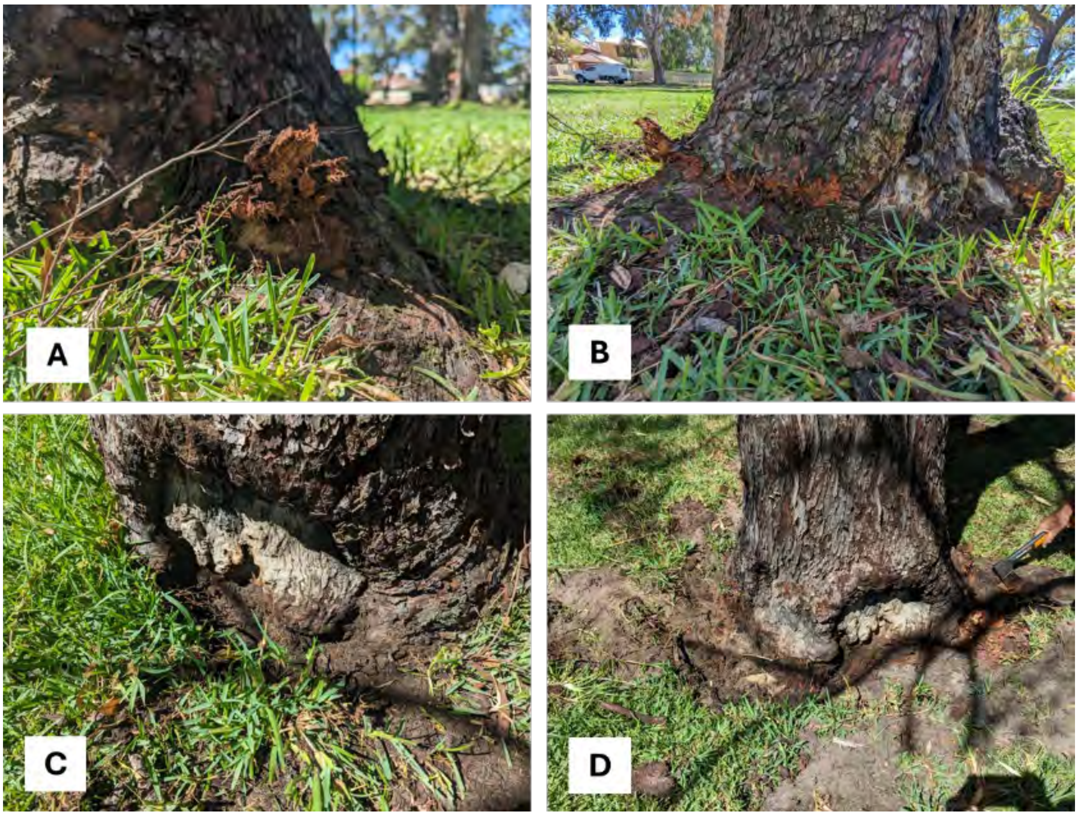


Figure 37: Mechanical damage to the root crown and basal stem (A and B), presumably due to mowing practices, resulting in ringbarking of the tree (C and D).

3.10 Urban Forest Inequity

Urban forest inequity refers to the unequal distribution and access to trees and natural spaces in urban areas. This issue is considered a form of environmental injustice, as it disproportionately affects marginalised communities. Numerous studies have identified a positive correlation between income and urban forest coverage. This introduces the concept of the "luxury effect," which explains that disparities in urban forest cover are linked to socio-economic and historical factors. The luxury effect demonstrates that wealthier areas tend to have higher biodiversity, reflecting the impact of socioeconomic status and education levels on the quantity and quality of green spaces in a given area. Furthermore, the unequal distribution of greenery in urban areas can limit the equitable sharing of the benefits provided by urban forests.

Frameworks can be developed for prioritizing planting in streetscapes and open space based on urban forest distribution and equity. Such framework can rank each street segment and park in order of necessity for planting. Prioritisation criteria could include current canopy cover, available planting space, temperature, population density, socioeconomic disadvantage, distance to green space, and active transport routes.

3.11 Data Management

Sustainable management of urban forests requires that data on tree type, location, size, and health be current, accurate, and easily accessible. The City currently does not have this information collected for its trees. The absence of a dedicated tree asset management system poses significant challenges for the City in sustainably managing its tree population. Inadequate high-quality data can lead to increased tree loss and replacement, inefficiencies in responding to resident requests, and a reactive approach to tree management. These issues can result in wasted funds and resources and a less healthy and expansive urban forest. Implementing a coordinated and specific tree management and data collection system as soon as possible is essential to address these challenges.

It is recommended that the City expand its use of software systems currently being utilised to improve the currency of data and tailor to the management of trees as important assets. In addition, the City should assign a new staff resource (Tree Asset Officer to ensure the inventory is maintained as an asset management database and manage the delivery of proactive tree maintenance programs. Canopy Cover and Urban Forest Targets

Canopy cover targets are an important component of any strategic document as they define how the success of the strategy will be evaluated in the future. They identify key metrics which can be reliably evaluated as an indicator of progress towards the overall goals and vision of the strategy. Periodic evaluation of strategy and policy is a key principle of adaptive management and allows refinement if the current approach is not meeting the required outcomes.

In the context of the urban forest, targets typically are focused on the extent and distribution of canopy cover, as this is regarded as a useful proxy for the range of environmental, wellbeing and amenity values provided by the urban forest.

To ensure targets are practical, they should reflect a balance between the goal of expanding canopy cover and the constraints the City faces. The method a City uses to manage these competing priorities should align with the values of both the local community and the City organisation.

3.12 Canopy Cover Targets

The following draft canopy cover targets have been developed based on Land Use (see Section 3.1.2 for baseline canopy cover figures). Some land uses have been further broken down into more granular categories, as necessary.

A detailed method of how the canopy cover targets were determined is presented in Appendix C.

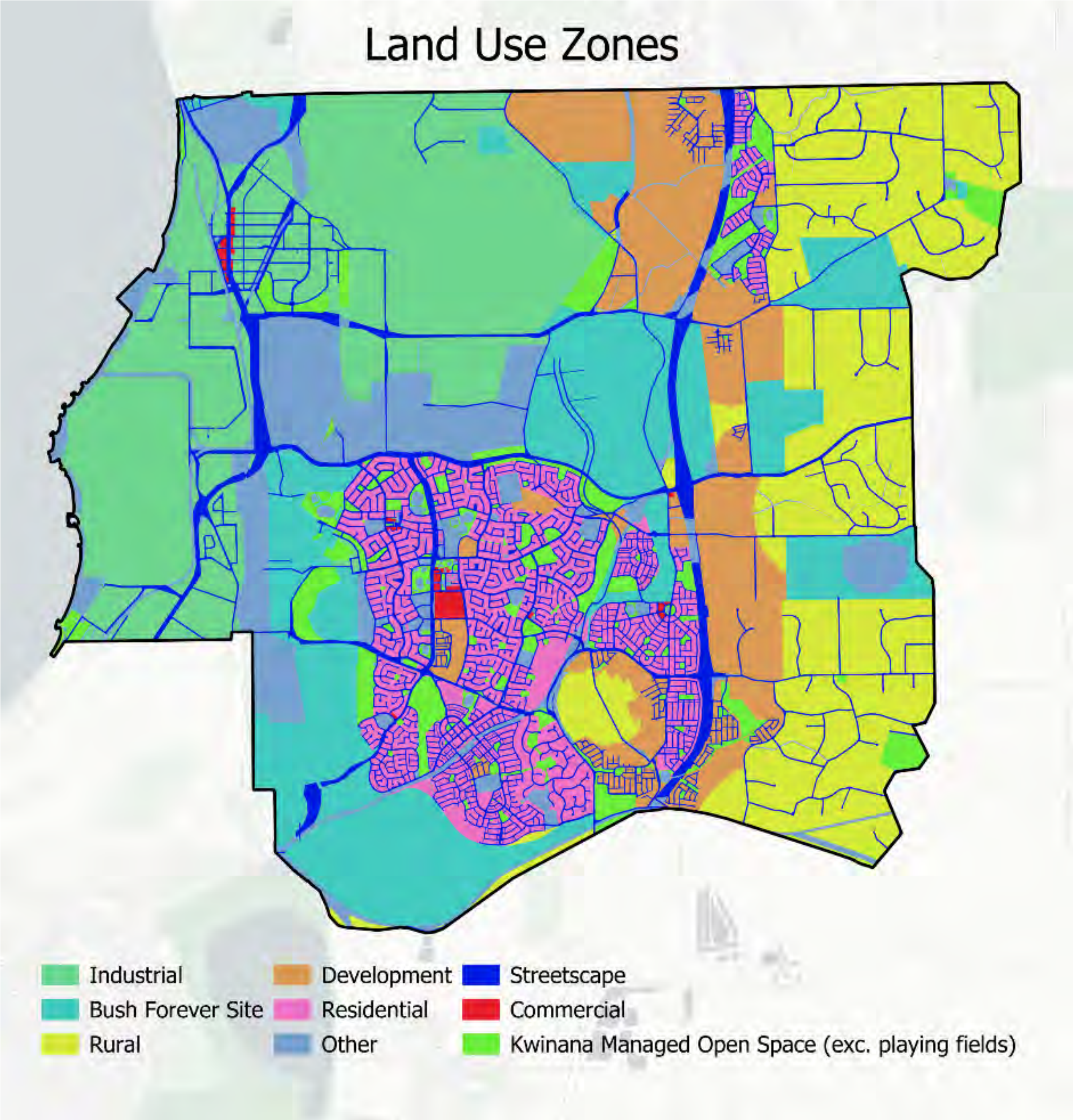


Figure 38: Land Use zones used to determine current canopy cover and set canopy cover targets.

The canopy cover targets proposed are designed to be realistic and achievable as a benchmark to evaluate the success of the Urban Forest Strategy.

Table 2 presents the canopy cover targets for each Land Use zone. The number of additional trees has been calculated using an average crown area of $50m^2$. The targets assume a 20-year strategy period, with all planting taking place in the first 10 years in order to realise canopy cover by the 20-year mark.

It should be noted that the targets are developed for Kwinana as an average (within each Land Use zone). **Not all land will be capable of reaching the target level. Therefore, individual lots or developments should aim to exceed these targets where possible.**

Table 2: Canopy cover targets for Land Use Zones. Number of additional trees have been calculated using an average crown area of 50m².

Land Zone	Current Canopy Cover (%)	Target (%)	Increase in Canopy Cover (ha)	No. of Additional Trees
Industrial	6.0	8.2	56	11104
Rural	31.0	31.0	0	0
Bush Forever Site	36.8	36.8	0	0
Development	13.3	17.8	59	11782
Other	16.0	16.0	0	0
Streetscape	10.9	22.9	145	28994
Residential	12.1	16.9	49	9796
Other Managed Open Space	43.3	43.3	0	0
Parks Managed Open Space	30.2	40.5	21	4216
Commercial	2.5	4.0	0.5	96
TOTAL LGA	**19.8**	**22.6**	**330**	**65,988**

To understand the impacts of the above targets for the Kwinana budget, the required additional canopy area was converted into a required number of trees. To meet the targets, an extra 330 ha of canopy cover is required across the whole City, 166 of which will be on Zones directly under the control of this Strategy (Streetscapes and Parks managed open space). This equates to 65,988 additional trees across the whole LGA, and 33,210 trees on Streetscapes and Parks managed open space. In order to reach the canopy target in 20 years, the majority of planting needs to take place in the next ten years. This equates to 6500 newly planted trees per year.

The target for Development, Residential, and Parks Managed Open Space have been further broken down (see Appendix D).

By distributing the Land Zone level targets among the suburbs, according to their land use proportions, it is possible to determine canopy targets at the suburb level (Table 3).

Table 3: Canopy cover targets broken down into Locality.

Locality	Current (%)	Target (%)	Increase in canopy cover (ha)	No. of Additional Trees
ANKETELL	16.2	18.7	16.8	3352
BERTRAM	11.8	17.7	18.8	3760
CALISTA	25.6	29.3	8.6	1718
CASUARINA	28.0	29.0	9.9	1976
HOPE VALLEY	8.5	10.4	25.8	5150
KWINANA BEACH	6.8	10.7	54.3	10858
LEDA	40.2	41.0	6.9	1386
MANDOGALUP	10.0	15.4	37.2	7448
MEDINA	32.7	35.2	9.3	1866
NAVAL BASE	7.9	12.4	22.9	4574
ORELIA	20.6	24.9	13.3	2668

PARMELIA	14.3	21.4	28.5	5696
POSTANS	14.7	16.2	7.3	1462
THE SPECTACLES	33.7	34.3	2.5	506
TOWN CENTRE	20.9	23.7	2.2	436
WANDI	23.8	25.1	16.0	3208
WELLARD	27.5	30.5	48.8	9752
TOTAL	19.9	22.6	329.1	65816

3.13 Other targets and indicators of urban forest health

Canopy cover is a metric widely used to measure the growth of an urban forest and the success of urban forest management. There are many advantages of measuring canopy cover – it is a simple, intuitive indicator of the extent of an urban forest. It is used worldwide, making it an acceptable benchmarking tool. Communities use it to set tree planting goals. It can also correlate to services provided (e.g., ecological services, stormwater management etc.) (Miller 1997). However, canopy cover measurements do not provide information about other important indicators of urban forest health and are required to manage and sustain an urban forest effectively. For example, canopy cover does not directly indicate species diversity, vegetation health, or age/size class distribution.

In general, all indicators relate to two themes of urban forestry (Ordóñez and Duinker 2013); tree loss/gain and tree diversity. They can also be separated into the type of measurement – quantitative or qualitative. To set a quantitative target, there is usually a baseline measurement. Since this is often not the case, and many indicators are difficult to quantify, many Councils use qualitative targets (e.g., to increase or build upon).

3.13.1 Structure

The ‘structure’ of an urban forest describes patterns in the spatial distribution of vegetation (Fan *et al.* 2019). This includes both vertical (i.e., ground cover, understorey vegetation, canopy cover, and all vegetation height strata) and horizontal distribution across landscapes and within land use boundaries.

Connectivity of vegetation within the landscape is important to promote the movement of native fauna within and across the urban area. This supports the transfer of genetic material between populations which can support genetic diversity and ecosystem resilience, as discussed below. In the urban setting this is typically achieved by establishing biodiversity corridors. The City has identified and maintains several biodiversity corridors, described in the City’s Local Biodiversity Strategy, 2022.

3.13.2 Genetic and Species Diversity

Genetic diversity refers to the genetic variability within a population, which can occur at multiple scales, both within species (e.g. intraspecific diversity) and between species and other taxonomic groups. Greater genetic diversity is associated with increased resilience to disturbance (Kendal *et al.* 2014).

In the urban forest context, maintaining genetic diversity is an important way to promote a healthy and resilient urban forest. Santamour (1990) proposed the 10/20/30 benchmark, which states that a municipality should aim for no more than 10% represented by a single species, no more than 20% represented by a single genus, and no more than 30% representation by a single family. However, it’s important to acknowledge the limitations of the benchmark and that it does not account for all competing priorities in species selection. It should not be used as a mechanism to reduce the abundance of local native species, where trees are primarily from the Myrtaceae family and the *Eucalyptus* genera. Despite its limitations, the 10/20/30 rule remains a useful rule of thumb (Kendal *et al.* 2014).

Lack of intraspecific diversity in urban forestry is the result of lack of genetic diversity in supply nurseries. Often in tree nurseries a few cultivars with known superior qualities are selected and clonally propagated, yielding plants of known and sound qualities, but with very little intraspecific diversity (Morton and Gruszka 2008). The use of a few widely distributed cultivars and clones may pose a risk to genetic diversity. Resulting in a population more at risk to pests and diseases. Intraspecific diversity is an issue that is difficult for the City to control if it continues to outsource tree stock from nurseries. The best way to decrease the risk would be to in-house tree supply and therefore have complete control over genetic diversity. Alternatively, the City should source stock from multiple suppliers to reduce risk of homogenisation. The City should also determine which trees are known to be cloned from one cultivar by contacting tree suppliers and avoid these trees if possible.

Intraspecific diversity is particularly important for exotic tree species. Native tree species planted in urban areas can transfer traits with native species in natural areas, and vice versa. Private trees also play a role in bringing diversity and resilience into an urban forest (Chambers-Olster, 2024), as these trees are often sourced from different suppliers than City trees.

3.13.3 Age-class Diversity

Age diversity and distribution is an indicator of urban forest health. A healthy urban forest has a reasonably even representation of age classes. To avoid an abrupt decline in the services an urban forest provides, it is important to understand its age structure and maintain its diversity (Song *et al.* 2018).

Age diversity of the City's current street tree population is not known due to the lack of a tree audit database. Recent strategies and papers indicate that age spread should be relative to the proportion of life that a tree spends in that age group. For example, a tree spends most of its life and provides the most benefits while in the 'mature' category, and therefore, a corresponding proportion of the City's tree population should be in that age category. There should be a balance of maximizing benefits of larger, more mature trees, with the intention to remove them when they reach their useful life expectancy (Pretzsch *et al.* 2021). Therefore, age-class benchmarks should reflect this. The City of Sydney adopted this age-class distribution in their recent Urban Forest Strategy Draft October 2022 (Table 4). Following the completion of a tree audit database, the City should review the data and adopt this age-class benchmark for their street tree population.

Table 4: Tree age classes and benchmark ranges, and their application to tree management, adapted from the City of Sydney Urban Forest Strategy 2022.

Age Class	Description	Indicative tree of 50-year life span Years within age class and % of life span	Benchmark range (City of Sydney)
Juvenile/young	Approximately the same size as nursery-grown advanced sized stock, easily replaceable	Years 0-5 10%	8-12%
Semi-mature	Not yet achieved a mature appearance and still actively increasing in biomass,	Years 6-20 30%	24-36%

	not easily replaceable from regular nursery stock		
Mature	Have grown to a size where biomass remains relatively constant	Years 21-50 60%	48-72%
Over-mature	Static or declining biomass and repeated symptoms of decline		Less than 1%

3.13.4 Health and Condition

Vegetation health and condition are important criteria that can be used to evaluate the success of forest management and support strategic planning. A sustainable urban forest requires healthy trees, and healthy vegetation will provide the maximum capacity of their ecosystem services (Clark *et al.* 1997).

Numerical targets for tree health are not commonly set as many Cities do not have robust data on the current health status of their trees and regular tree audit collection to compare change since the baseline is typically beyond the budget of most. The City of Melbourne set a target in their Urban Forest Diversity Guidelines 2011 to ensure that no more than 10% of their trees would be in poor health by 2040.

The City's existing airborne remote sensing data could be used to benchmark condition, to be measured against future acquisitions.

3.13.5 Tree Survivorship/Rate of Mortality

Urban tree survival is essential to sustain the ecosystem services of urban forests, and monitoring is needed to accurately assess benefits, and for Councils to reach their numeric canopy cover goals (Ko *et al.* 2015). Understanding the rate at which trees survive or die after being planted will enable accurate estimations on when canopy cover goals will be reached. Tree survivorship is the inverse of tree mortality.

The City of Kwinana should set a target to improve upon current levels of survivorship, and measure levels of mortality to take this into account for reporting on canopy cover targets. This will first involve measuring baseline mortality rates. This information can be collected and added to the existing street tree audit. Once a baseline figure has been determined, a target to increase survivorship can be set and measured regularly.

3.13.6 Native Biodiversity

Biodiversity is a broad term, but in this context, it relates to the variety of organisms (plant, animal and microbial) that are endemic to the region that the City of Kwinana is a part of – the south-west of WA. Global efforts at mitigating biodiversity loss often focus on preserving large, intact areas of natural habitat. However, the continuing trend towards urbanisation increases the importance of biodiversity in urban areas as well. Biodiversity determines many ecosystem functions and underlying services, while contributing to the overall resilience of ecosystems (Roeland *et al.* 2019).

Biodiversity can be assessed and measured by several criteria, including habitat provision (Roeland *et al.* 2019), connectivity (Ordonez and Duinker 2013), species diversity, and the abundance of invasive species.

Qualitative goals include protecting and extension of habitat connectivity and habitat corridors. The City of Kwinana has developed a Local Biodiversity Strategy to address these challenges and provide targets. Its primary goal is to recover and conserve existing biodiversity and environment.

4 Equitable Tree Canopy and Prioritisation Map

Within Kwinana, there are some areas that have significantly lower canopy cover than others. Tree equity is important because it means that everyone in the community has access to trees, quality green space and the benefits they provide.

The following broad-scale prioritisation plan has been developed as a guide for the Council to spatially prioritise greening efforts. The purpose is to create a more equitable distribution of canopy cover within the City and to maximise the benefits provided by future investment in street tree planting. It provides the Council with guidance of where the actions outlined in the Implementation Plan should be prioritised, and ensures that tree equity is embedded into the urban forest planning.

The prioritisation map (Figure 39) is based on locality, and considers the:

- Current canopy cover of the locality
- Available planting space of each locality
- Median land surface temperature of each locality
- Presence of statistically significant heat islands (identified in Section 3.1.4)
- Index of Relative Socio-Economic Disadvantage (IRSD; ABS) for each locality
- Population density (ABS) of each locality
- Distance of each lot in each locality to open space

Each locality was ranked on each feature and split into quantiles. A priority score of one to four was assigned to each locality depending on its ranking. The priority score for each feature was summed to create the combined prioritisation score for each locality ranging from 1 to 17, 1 being the highest priority for planting, and 17 being the lowest priority.

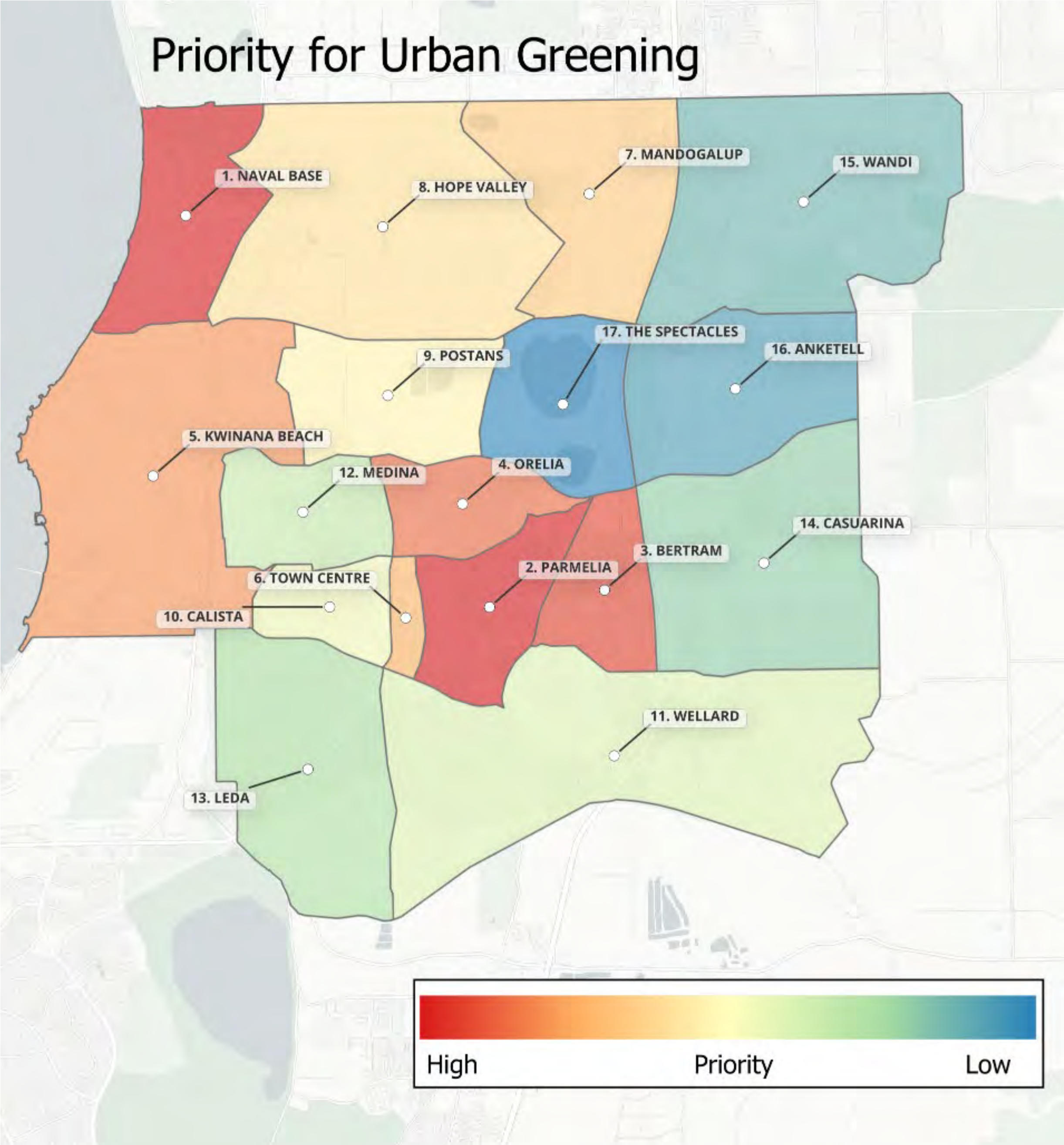


Figure 39: Localities in the City of Kwinana ranked by planting priority.

5 Implementation Plan

This Implementation Plan provides a roadmap to translate the City's urban forest vision.

The actions are prioritized as high (within 2 years), moderate (3-5 years), low (5-10 years), and ongoing (throughout the Strategy duration).

Successful implementation of this plan will require the integration of targets with the capabilities and resources required to establish and maintain a resilient urban forest. These actions will need integration into operations planning to ensure their implementation.

Table 5: Table 6: Actions implementation table, prioritised as high (within 12 months), moderate (2 – 3 years), low (4 – 5 years), or ongoing (throughout the Strategy duration).

PROTECT, RENEW AND VALUE					
Principals	**Action**	**Section**	**Priority**	**Resourcing**	**Responsibility**
1 Protect	Undertake a review of internal and external (i.e. City of Nedlands, Town of Cambridge) initiatives for tree protection on private land, determine the most suitable initiative(s), and finalise for review by Council.	4.1	HIGH	No additional funding required	Strategic Planning
2	Undertake a review and update of LPP No. 1 and the Street Trees and Verge Treatments Policy to improve the survival and longevity of the City's urban trees	4.1.2	HIGH	No additional funding required	Strategic Planning Tree Management Team
3	Explore current penalties and opportunities for review for any damage caused to City trees. Calculate tree value and loss of asset for lack of protection of trees during development. Loss of asset to be invoiced for calculated values.	4.2.1	HIGH	No additional funding required	Tree Management Team
4	Investigate how existing airborne data can be used by the City to enforce compliance, reducing the impact on City resources.	4.2.1	HIGH	No additional funding required	Tree Management Team
5	Undertake a tree audit/asset register for Council managed trees (streetscapes and Parks managed open space) including the valuation of trees using a recognized methodology.	4.2.1	MODERATE	Additional funding required (Consultant $450K)	Tree Management Team

6	Develop a georeferenced tree database with filtering by host, pest or pathogen risk for the spatial investigation of their risk profiles.	4.3	MODERATE	Additional funding required (Consultant $30K)	Tree Management Team
7	Ensure Tree Protection Zones (TPZ) and Structural Root Zones (SRZ) are protected during construction and development and amend Local Planning Policy No. 2 to include provisions for this.	4.5	HIGH	No additional funding required	Environmental and Strategic Planning
8	Advocate for aerial bundled cables for neighbourhoods with above ground power supply, prioritizing areas with a higher proportion of mature/large/significant trees that provide significant canopy cover and are adversely impacted by powerline clearance pruning. Advocate for underground power distribution where possible.	4.5	LOW	No additional funding required	Tree Management Team
9	Review existing methodologies for improving tree diversity and resilience and develop a customised approach for the City's tree population.	5.1.2	MODERATE	No additional funding required	Tree Management Team
10	Consider in-housing tree supply or partnering with other LGAs, to have control over tree genetic diversity. Alternatively, source tree stock from multiple suppliers, and give preference to those suppliers that take genetic diversity into consideration.	5.1.2	MODERATE	Additional funding required (dependent on scenario)	Tree Management Team
11 Expand	Ensure developers are required to plant trees upon completion of development, and stock has been grown according to AS 2303:2018	4.1.2	HIGH	No additional funding required	Statutory Planning
12	Prioritise areas of dead grass, exposed soil, and available planting locations in the lowest canopy cover areas, for tree planting, to reduce the local UHIE and improve amenity value	4.4	ONGOING	No additional funding required	Tree Management Team
13	Develop a streetscape and open space planting prioritisation framework based on urban forest distribution and equity.	4.10	MODERATE	Additional funding required (Consultant $10K)	Tree Management Team
14	Trial new species identified as climate resilient for their suitability for planting throughout the City. This will	5.1.2	MODERATE	No additional funding required	Tree Management Team

	require forward planning on behalf of the City to ensure nurseries have appropriate stock.				
15	Implement a regular and continuous tree planting program to ensure a greater age distribution, including targeted succession planting of the City's aging tree population. Plant large, long-lived trees to improve the continuation of canopy cover.	5.1.3	ONGOING	No additional funding required	Tree Management Team
16 Monitor and Manage	Develop a Street Tree Masterplan for the City with a focus on resilience to abiotic and biotic disorders and the survival and longevity of the City's urban trees.	4.1.2	MODERATE	Additional funding required (Consultant $50K)	Tree Management Team
17	Explore the use of airborne remote sensing data to geolocate trees on new verges to ensure compliance, and for monitoring their growth and health over time.	4.1.2	HIGH	No additional funding required	Tree Management Team
18	Utilise the baseline airborne data for identification of significant trees, and use change detection imagery from subsequent acquisitions to monitor impacts to tree cover and condition. Explore the extraction of condition data at the individual tree level from the airborne data for early warning of abiotic and biotic factors.	4.2.1	MODERATE	Additional funding required (Consultant $50K)	Tree Management Team
19	Investigate opportunities to collaborate with qualified forest pathologists to trial methods for the management of various abiotic and biotic factors, if and when they arise.	4.3	HIGH	No additional funding required	Tree Management Team
20	Explore methods for targeted watering of individual trees throughout the City based on their requirements and risk profile	4.4	HIGH	No additional funding required	Tree Management Team
21	Undertake a full audit of all trees throughout the City, followed by targeted field collection of attributes	4.6	HIGH	Additional funding required (Consultant $450K)	Tree Management Team
22	Following the completion of the tree audit, analyse the data to determine the species and age-class profile, and	4.6	MODERATE	No additional funding required	Tree Management Team

	develop a desired genus, species and age-class profile for the City.				
23	Undertake a feasibility study to determine the adequate costs required to effectively manage and maintain trees, and determine whether this is best implemented internally, externally or through a combination of both	4.9	MODERATE	No additional funding required	Tree Management Team
24	Explore opportunities to combine canopy cover acquisitions with other LGAs to achieve efficiencies.	4.11	MODERATE	No additional funding required	Tree Management Team
25	Expand the use of currently utilised software systems to improve currency of data and tailor to the management of tree assets. Explore asset management systems that are tailored to the management of the urban forest.	4.11	HIGH	No additional funding required	Tree Management Team
26	Assign a dedicated new staff resource (Tree Asset Officer) who will manage and maintain the tree asset management database, and manage the delivery of proactive tree maintenance programs.	4.1.1	HIGH	Additional funding required	Tree Management Team
27	Manage trees to their full ULE and avoid removal of mature trees unless necessary due to unacceptable risk. Implement a standardised assessment framework for tree removal.	5.1.3	MODERATE	No additional funding required	Tree Management Team
28	Adopt an age diversity target relative to the proportion of life a tree spends in that age group.	5.1.4	LOW	No additional funding required	Tree Management Team
29	Record all tree deaths in a tree asset database and report annually on the mortality, age, species, supplier and cause. Summarise mortality rates by species to identify trends in species performance.	5.1.5	ONGOING	No additional funding required	Tree Management Team
30 Collaborate, Educate and Incentivise	Review and collaborate in research to benchmark the drought and heat stress tolerance of the existing tree population and potential species for future planting.	4.3	MODERATE	No additional funding required	Tree Management Team
31	Incentivise the community to water their verge trees, and where possible, apply mulch to verge trees prior to the	4.4	HIGH	No additional funding required	Sustainability and Environment

	spring/summer period to conserve soil moisture.				
32	Develop and implement an annual communications plan for residents. This should include information around the benefits trees provide, including real-estate values, and decreased energy consumption.	4.8	HIGH	No additional funding required	Sustainability and Environment
33	Improve engagement of the community with the City's urban forest through the display of aerial datasets on a dedicated interactive webpage.	4.8	MODERATE	No additional funding required	Sustainability and Environment
34	Improve Council engagement during tree planting programs. Involve the nearby community in watering newly planted trees, e.g., by providing information on the species and how to look after it.	4.8	HIGH	No additional funding required	Tree Management Team
35	Collaborative actions should be investigated by the South West Metropolitan Regional Alliance as a potential program	4.8	MODERATE	No additional funding required	Tree Management Team

6 Financial Implications

The current rate of tree planting is insufficient to achieve an increase in tree canopy cover. The funding available is not enough to increase tree planting efforts and proactively manage tree maintenance. Lack of funding was identified as a major limitation to the City's current greening efforts. While there are efficiencies that can be made, inevitably increased funding is required to achieve the targets. To ensure that the City's responsibilities and targets are met, suitable capital and operating budgets should be provided.

The City receives grant funding that is uses to undertake additional work within its reserves, but this funding is unreliable so cannot be counted on. In addition, a significant portion of the increase in required funds is associated with planting trees in streetscapes.

7 Monitoring and Review

The progress of each action in the Implementation Plan should be reviewed annually against an internally set measure of success, taking into account their priority. The progress towards the canopy cover targets should be monitored by follow up aerial data acquisition every two years. Reliable, repeat measurements of canopy cover will allow for reasonable control limits to be set, and any significant changes in canopy cover to be identified early – increases will indicate that management programs have been successful, while decreases will indicate that they have not – and the necessary intervention can be made.

The urban Forest Strategy will be reviewed in full every five years.

The City of Kwinana will continue to monitor for any relevant changes in State and Federal government that will impact urban greening efforts, positively or negatively, and respond to them appropriately.

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Appendix A – Development of Land Use boundary and source of boundaries

The Land Use boundary used to determine canopy cover and available planting space statistics, and canopy cover targets, was developed from several GIS boundaries provided by the City or from the Western Australian government online data sources. The table below provides the mapping of each GIS boundary feature to Land Use category, in order of hierarchy.

Table 7: GIS boundaries used to develop the Land Use boundary, their sources and description.

Source file	Boundary	Classification feature	Land Use Category	Modifications
kwinana_roads_polygons.geojson	Road polygons	Land_type	Streetscape	N/A
Open_Spaces.shp	Open space	Name_Descr Manage-By	Kwinana Managed Open Space	Manually excluded sports fields, Categorised according to size
LPS4.shp	Local Planning Scheme 4	Centre	Commercial	N/A
		Centre (Local)	Commercial	
		Cluster/communal rural settlement	Rural	
		Commercial	Commercial	
		Development	Development	
		General industry	Industrial	
		Hope Valley - Wattleup Redevelopment Act	Industrial	
		Improvement Plan 47	Development	
		Light industry	Industrial	
		Mixed Use	Other	
		No zone	Other	
		Park recreation and drainage	Other	
		Private clubs, Institutions and Place of Worship,	Other	
		Public Open Space	Other	
		Public purposes	Other	
		Residential	Residential	
		Rural	Rural	
		Rural A	Rural	
		Rural Residential	Rural	
		Rural Smallholdings	Rural	
		Rural water resource	Rural	
		Service Commercial	Commercial	
		Service commercial	Commercial	
		Special residential	Residential	
		Special rural	Rural	

		Special use	Other	
		Town centre residential	Other	
		Urban Development	Development	
Region Scheme-DPLH022.shp	Bush Forever Sites	Descriptio	Bush Forever	N/A
		Remaining area in LGA boundary	Other	N/A

Table 8: Other boundaries and their uses.

Source file	Boundary	Classification feature	Use	Modifications
Local Planning Scheme - R Codes (DPLH-070) (ArcGIS REST Server)	Residential codes	R code number	Analysis of subdivision infill and canopy cover targets	N/A
Kwinana SLIP Cadastre.shp	Cadastral/lot	land_type	Land tenure and analysis requiring lot boundaries	Where features overlapping, flattened to single feature
N/A	Various Structure Plans	N/A	Used to categorise the Development land use category for use in canopy cover targets	

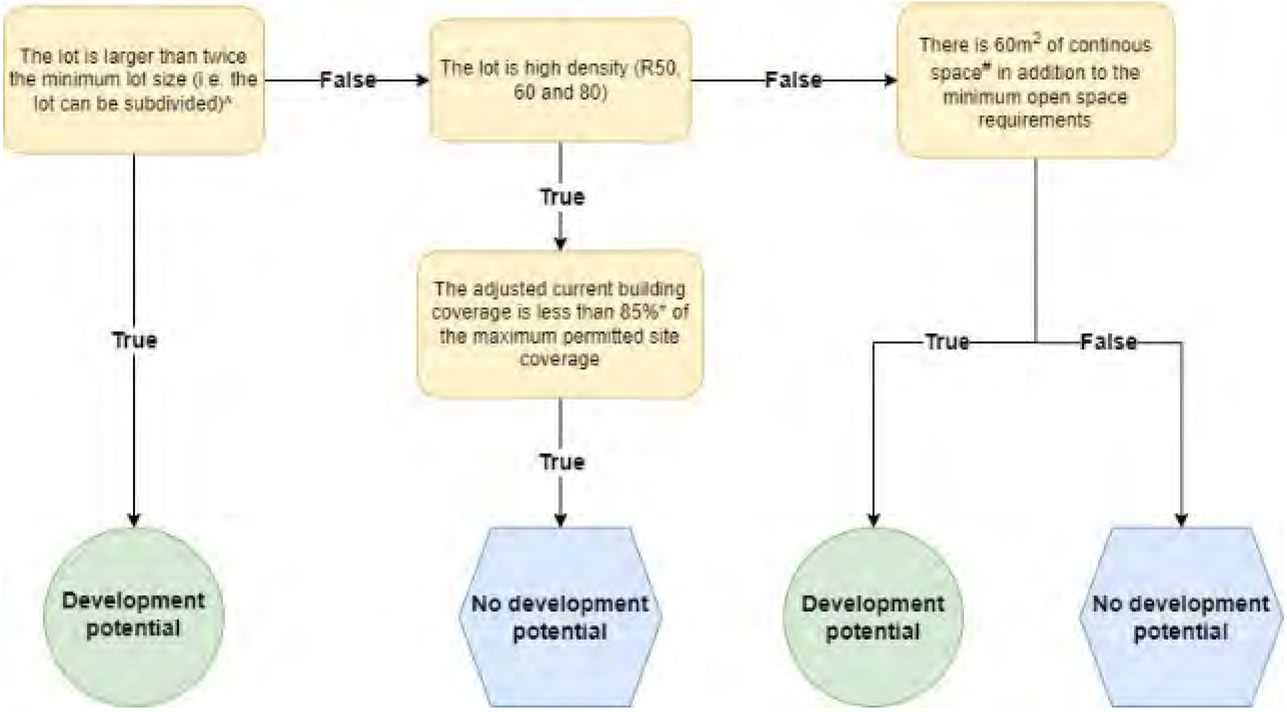
Appendix B - Method of Modelling the Potential Impact of Subdivision Infill on Canopy Cover

Analysis was conducted on residential lots according to their R-codes (see State Planning Policy (SPP) 7.3 – Residential Design Codes Volume 1 and 2 for specifications). Building footprints were downloaded from the National Housing Data Exchange (https://housing-data-exchange.ahdap.org/). The R-code specifications used to determine whether a lot was considered as having development potential were:

a) Site area per dwelling (m^2)
   i. Applicable to lots classified as all R-codes.
   ii. Lot is considered to have development potential IF the lot is larger than twice the minimum or average lot size (i.e., the lot can be subdivided).
b) Minimum open space (%)
   i. Applicable to low-density lots with single dwellings (classified R-codes R2 to 40)
   i. Lot is considered to have development potential IF the current open space/non-building coverage exceeds the minimum open space requirement by at least $60m^2$ of continuous space.
c) Maximum site coverage estimation (%)
   i. Applicable to high-density lots with multiple dwellings (classified R-codes R50 to 80 and RAC-0).
   ii. Lot is considered to have development potential IF the current building coverage is less than 85% of the maximum site coverage.

Overall, a Property lot was considered to have development potential if it met the requirements of a), b) or c). This resulted in each residential cadastral lot either having development potential or not.

The methodology is summarised in the flowchart below, and the assumptions and limitations of the methodology are provided.



Assumptions:

- If a dual R-code was specified, specifications of the first R-code were used.
- If R-code specifications provided both a minimum and an average lot size requirement, the average was used in the analysis.
- 90% (capacity minus 10%) was used to account for residents' lack of desire to build to capacity.
- 60m^2 of continuous space would account for significant development on a single dwelling e.g., the addition of a granny flat.
- Although R40 is considered high density, this analysis considers it a low density/single dwelling (under SPP 7.3 Volume 1).
- Volume 1 is single and grouped dwellings; Volume 2 is apartments.
- The maximum site coverage estimation of high density lots was determined by using the smallest value of either the:
  - Lot area multiplied by the plot ratio (assuming single story and based on plot ratio)
  - Lot area minus the setbacks (assuming double story, as increasing the story would decrease the site coverage percent, and assuming the 'worst case scenario'/least available space).

Limitations:

- Calculation of lot area minus setbacks assumes a square lot.
- The outcome is a 'worst case scenario' as it assumes all lots with development potential will be developed.

Appendix C – Method for Canopy Cover Target Development

Different methods to develop canopy cover targets have been tailored to suit Kwinana, dependent on land use type. These methods are adapted from other LGAs and techniques developed by ArborCarbon, and are outlined below.

Land Use Classification	Canopy Cover Target Method
Bush Forever Site	No loss/change.
Commercial	Bringing each lot up to mean canopy cover# for all commercial zones.
Development	Assume all vegetation cleared and then apply targets based on land use (provided in structure plans). Use Land Use targets from established part of the City. If particular R-code does not exist within established part of Kwinana, use canopy cover from nearby Council.
Industrial	Bringing each lot up to mean canopy cover# for industrial zones.
Parks Managed Open Space	Based on each park achieving aspirational canopy cover (increase of 20%) for park categories.
Other Managed Open Space	No loss/change.
Other	No loss/change.
Residential	Bringing each lot to the mean canopy cover# for that R-code. If no R-code, bring each lot to the mean of all lots with no R-code.
Rural	No loss/change.
Streetscape	Aspirational target calculated using Available Planting Space.

The current canopy cover within each cadastral lot and road segment was determined along with the mean value within each Land Zone. All lots which were below the current mean value for their respective Land Zone were identified as having potential for canopy increase. The canopy cover target was determined by adjusting the canopy cover of all lots with potential to increase canopy to match the current Land Zone mean. The total canopy area was then summed to calculate the new mean for all precincts which was used as the baseline canopy target. The intention of this approach is to set a target which falls within the current range of typical values observed in the LGA and therefore within the capacity of land and expectations of the community to support the additional tree canopy.

This approach is particularly useful for forecasting likely canopy outcomes following greenfield development sites. This analysis shows that residential development of these sites is likely to have a net positive impact on tree canopy cover once the properties and new trees are established. However, this should not be interpreted as a reason for complacency, as the targets represent substantial increase on the current residential canopy cover, and will be challenging to achieve, without policy action. Furthermore, changes in LPS and housing trends can greatly affect outcomes for the urban forest.

Appendix D – Granular breakdown of Development, Residential and Parks Managed Open Space

Table 9: Canopy cover targets for Development.

Development Structure Plan Land Use		Total area (ha)	Current (%)	Target (%)
Residential	R10	2.0	11.6	20.3
	R12.5	1.4	6.3	19.7
	R20	17.2	2.9	7.5
	R25	115.6	14.5	17.8
	R30	176.4	4.7	6.1
	R40	35.6	9.9	31.6
	R50	9.0	3.1	6.9
	R60	26.2	29.1	31.2
	R80	6.7	50.1	50.5
	No R-code)	44.4	16.6	18.9
Commercial		36.0	7.5	9.9
Industrial		235.6	3.1	8.5
Neighbourhood Centre		0.2	55.8	55.8
Open Space		126.2	27.3	42.8
Public Purposes		10.3	28.5	30.9
Special Use		6.5	0.0	13.9
No Structural Plan		394.6	17.9	19.8
TOTAL DEVELOPMENT		**1243.9**	**13.3**	**19.1**

Table 10: Canopy cover targets for Residential.

R-code	Total area (ha)	Current (%)	Target (%)
No rcode	342.4	7.4	12.3
R12.5/20	403.1	14.3	19.7
R20	175.1	3.6	5.7
R25	5.3	6.6	10.3
R30	3.3	1.9	3.1
R30/100	0.7	1.9	3.1
R40	16.7	23.5	30.7
R40/50	0.3	4.6	4.8
R5	79.2	39.7	45.4
TOTAL RESIDENTIAL LAND	**1026.1**	**12.1**	**16.9**

Table 11: Canopy cover targets for Parks managed open space..

Category	Total area (ha)	Current (%)	Target (%)
Disctrict	75.6	29.0	40.6
Local	0.3	35.6	47.7
Neighbourhood	14.6	22.9	33.4
Regional	113.4	31.9	41.4
TOTAL PARKS MANAGED OPEN SPACE	**203.9**	**30.2**	**40.5**

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