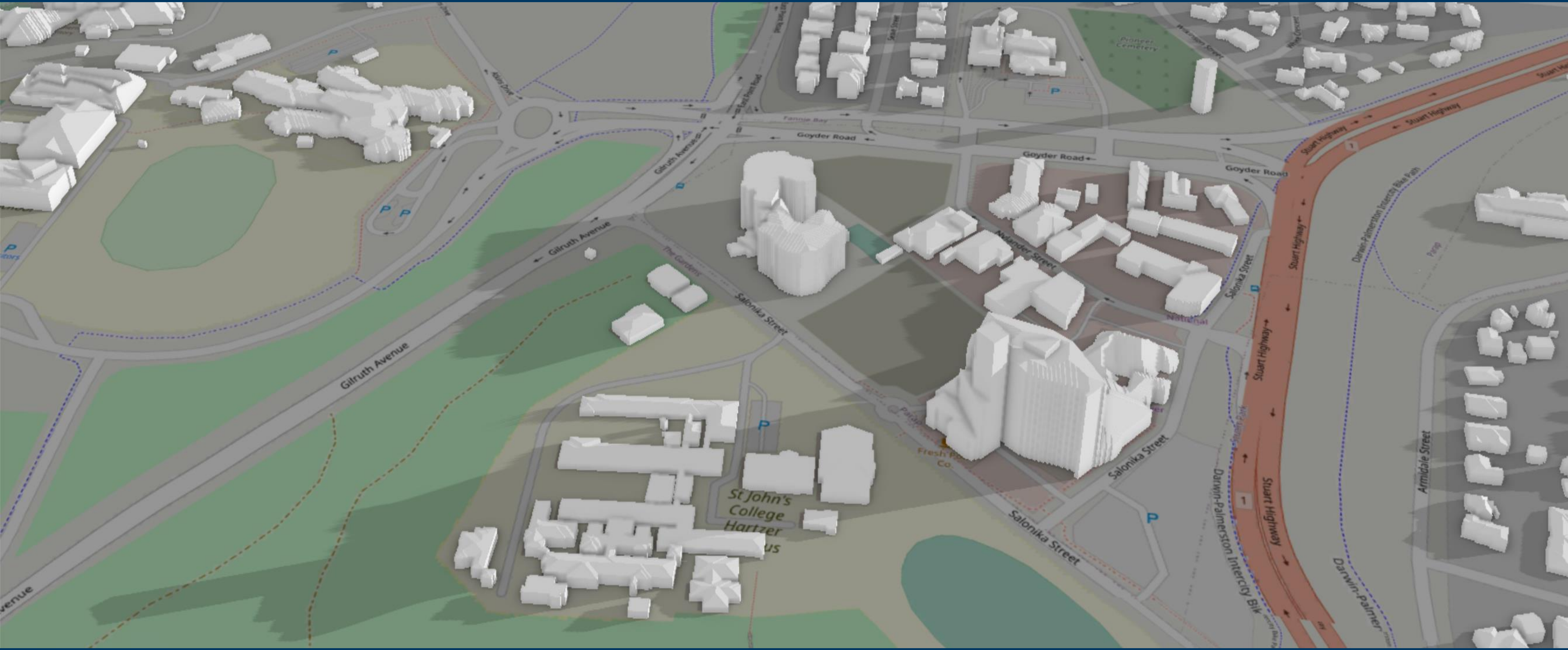
A Digital Twin of Darwin to inform urban planning.

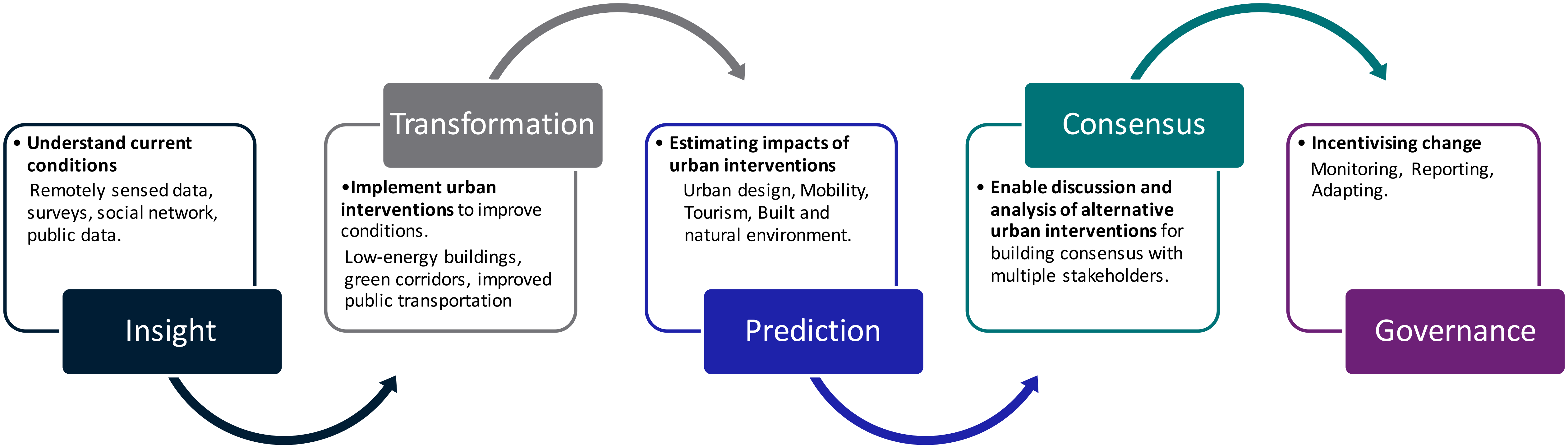


Raymundo Marcos-Martinez, Sorada Tapsuwan

Darwin Living Lab

How can we transform Darwin into a ________ city?

green
cool
vibrant
prosperous
...



Source: Adapted from MIT media lab

Our definition of a digital city twin.

A virtual representation of the built, natural and socioeconomic environment of a city.

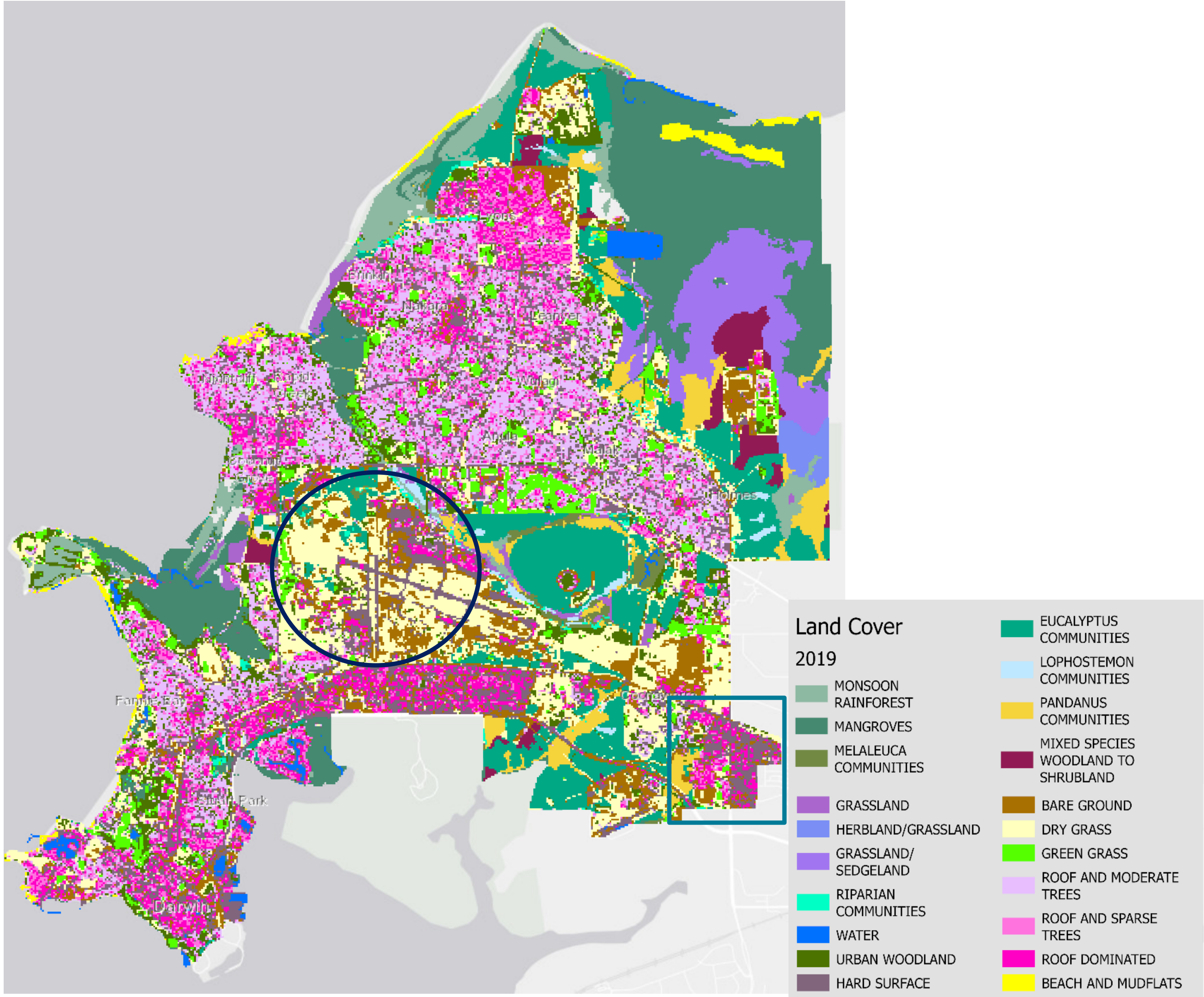
Science and data driven models of the processes, interactions, and dynamics of different components of a city.

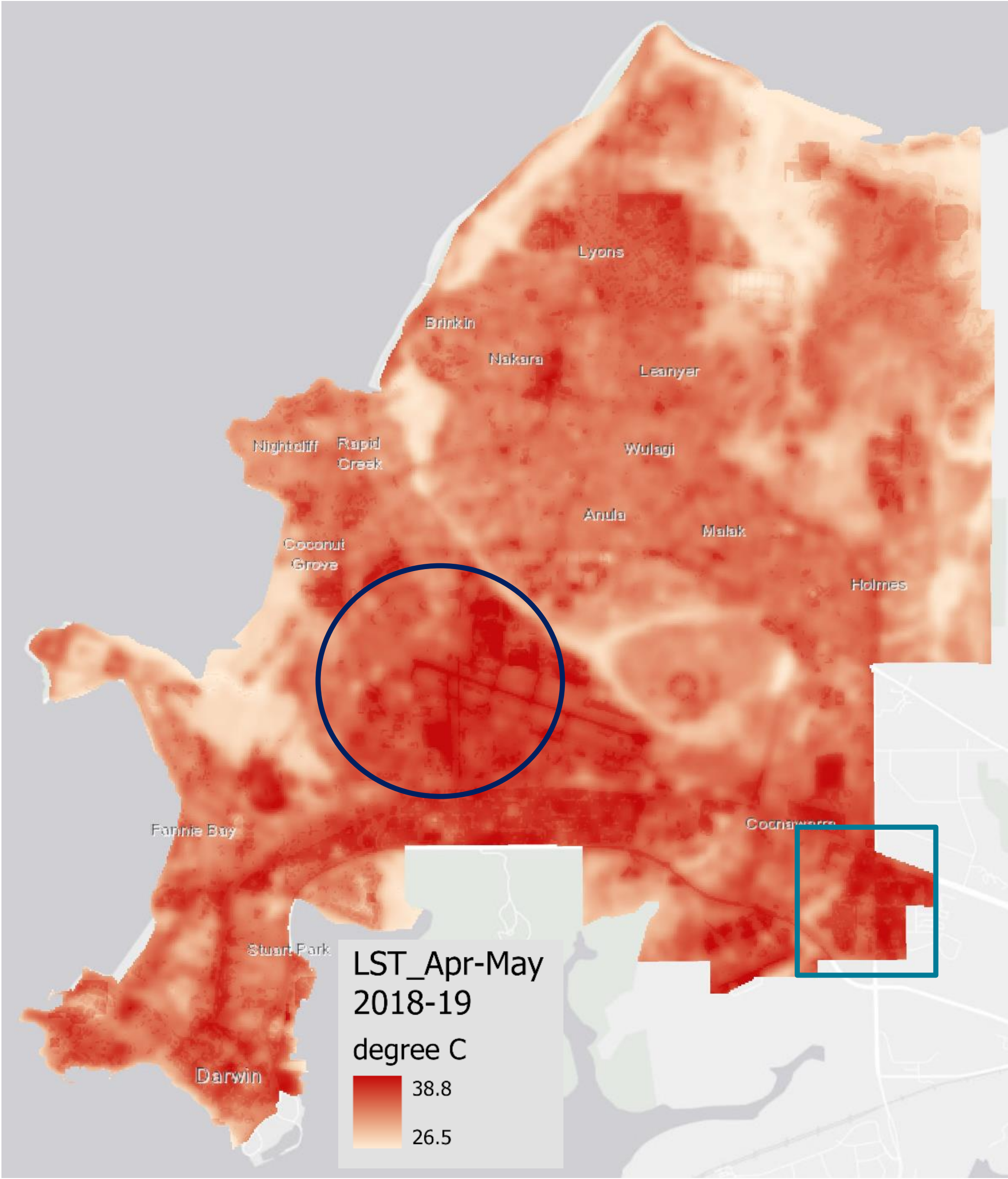
Interactive solutions, tools and models to gain insights into the potential benefits, costs and opportunities of targeted interventions.

A responsive and adaptable platform for complex analysis at different spatial and temporal scales.

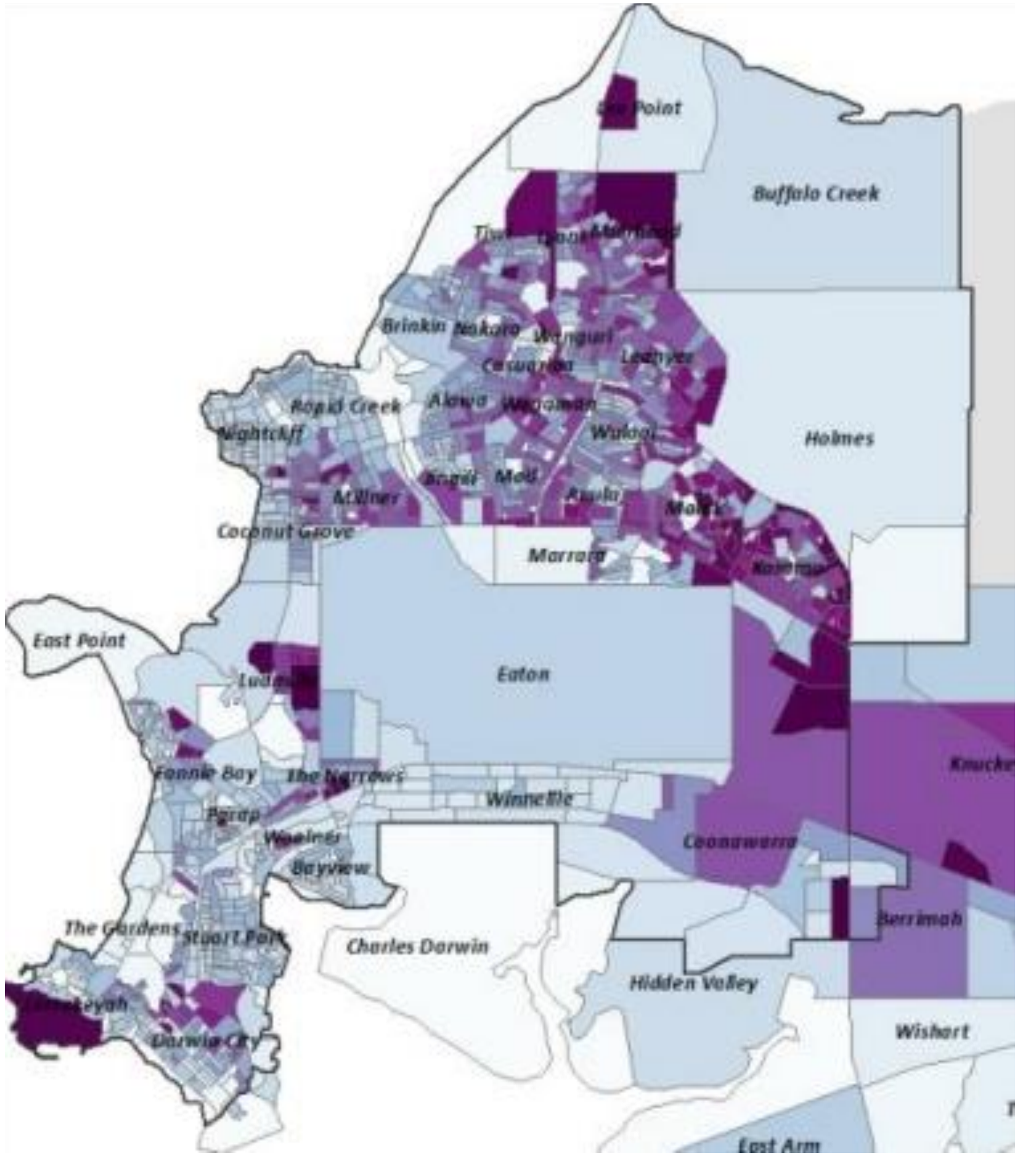
Accessible to non-technical users.

A virtual urban environment: Land use mapping





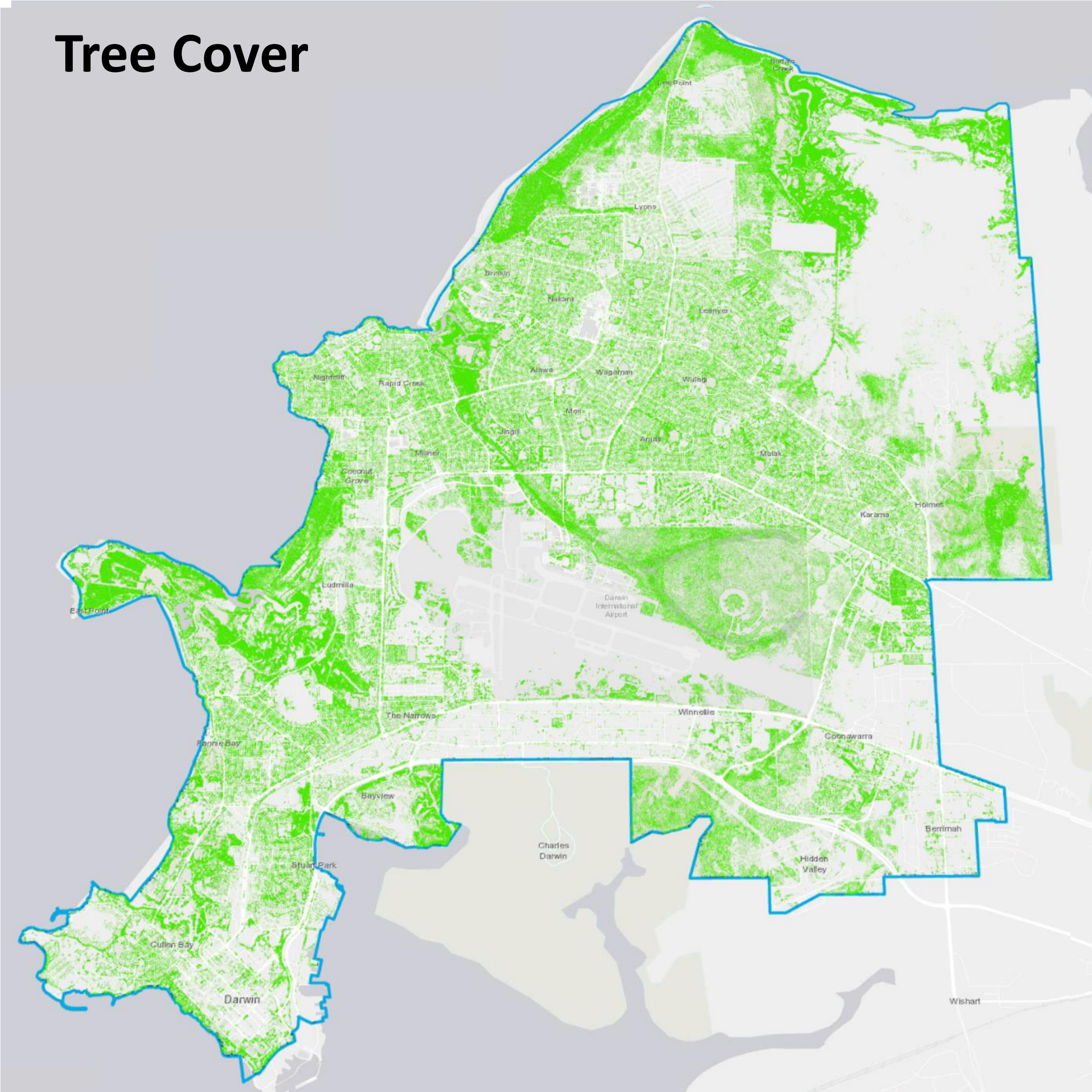
A virtual urban environment: Heat Vulnerability



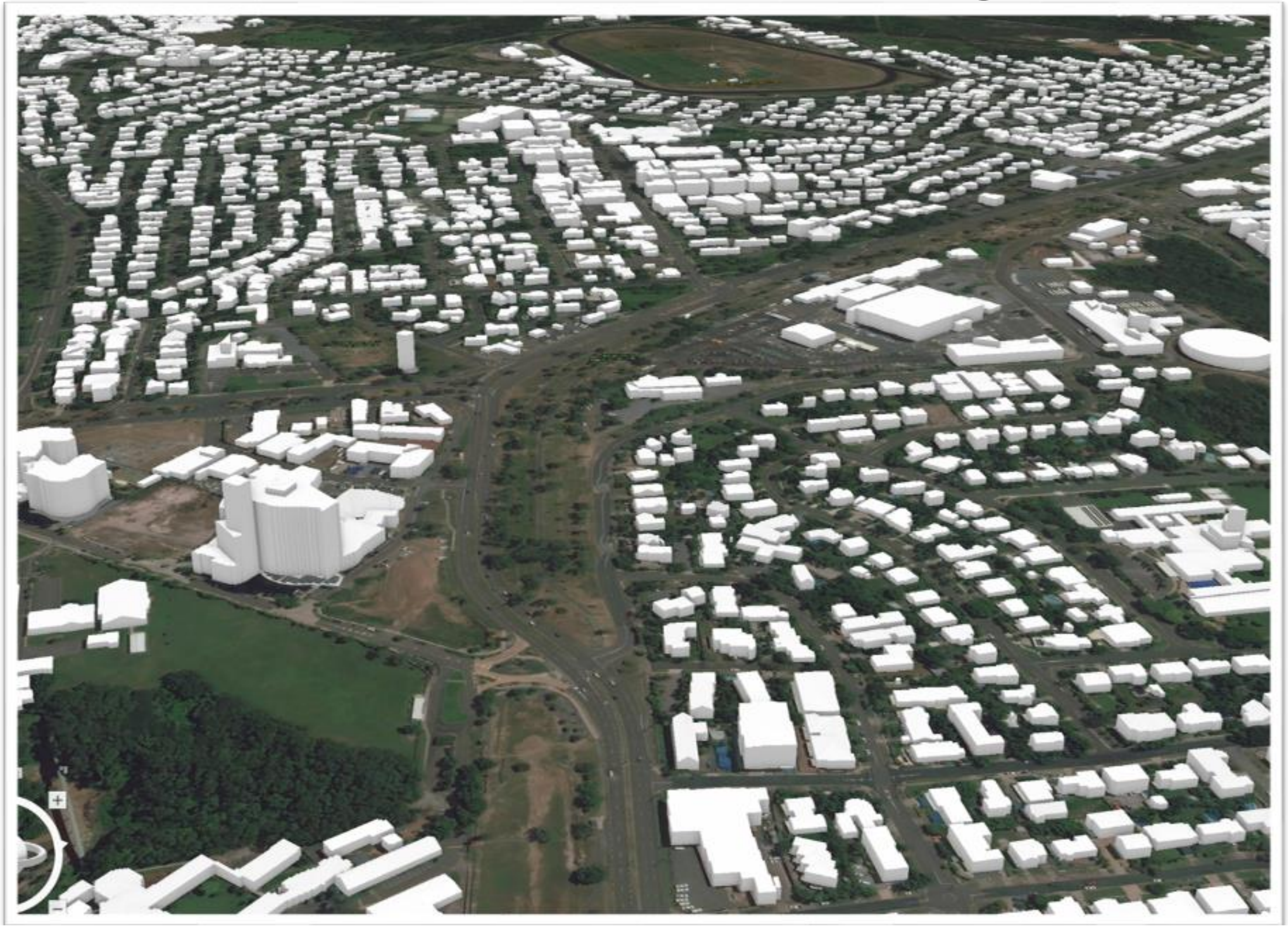
Highest vulnerability (100)

Lowest vulnerability (0)

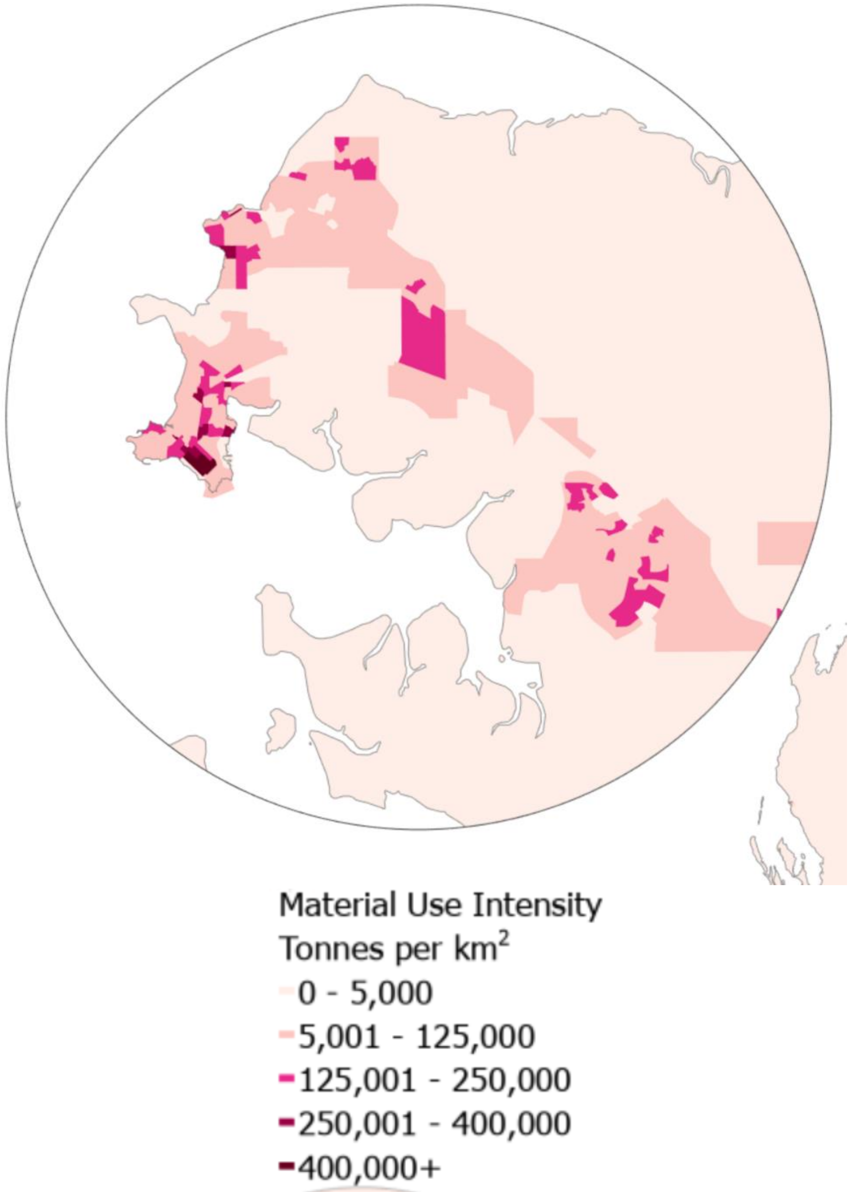
Urban monitor data (20 cm resolution-- 2011, 2016, 2021)



A virtual urban environment: Buildings



Science and data driven models: Embodied materials



- Tonnes of materials in buildings and their environmental footprint (emissions, water, energy).
- Project material demand and environmental footprint for replacing ageing buildings and constructing new ones for a growing population.
- The construction industry accounts for 44% of all waste in Australia.
- Significant potential for recycling
- Transformation needed not only in building operation but in building construction technologies.

Science and data driven urban models.

Tree canopy cover (TCC):

2011: 191 ha

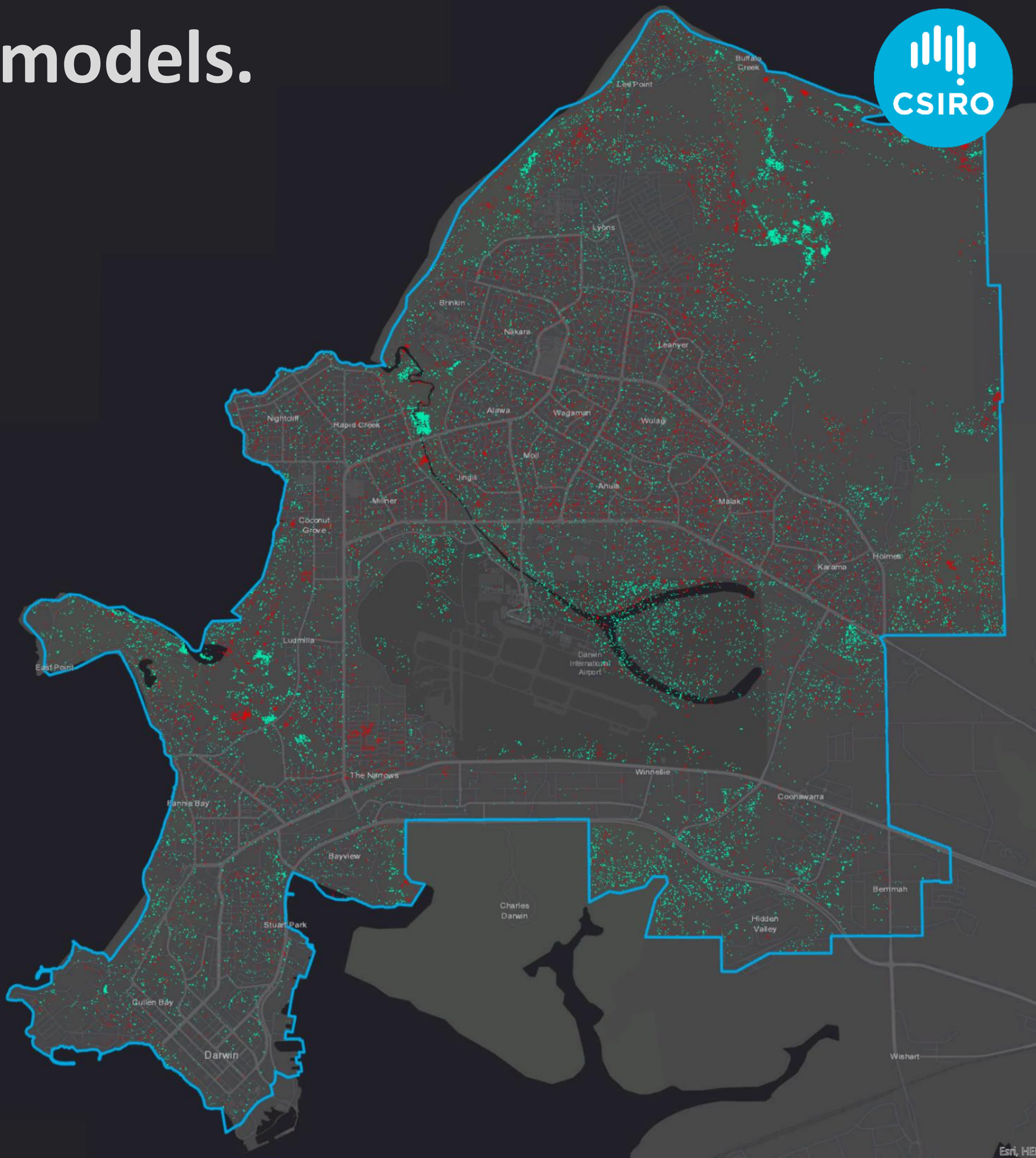
2016: 206 ha

Net gain: 15 ha (8% of 2011 TCC)

TCC per capita:

2011 -> 26.21 m^2

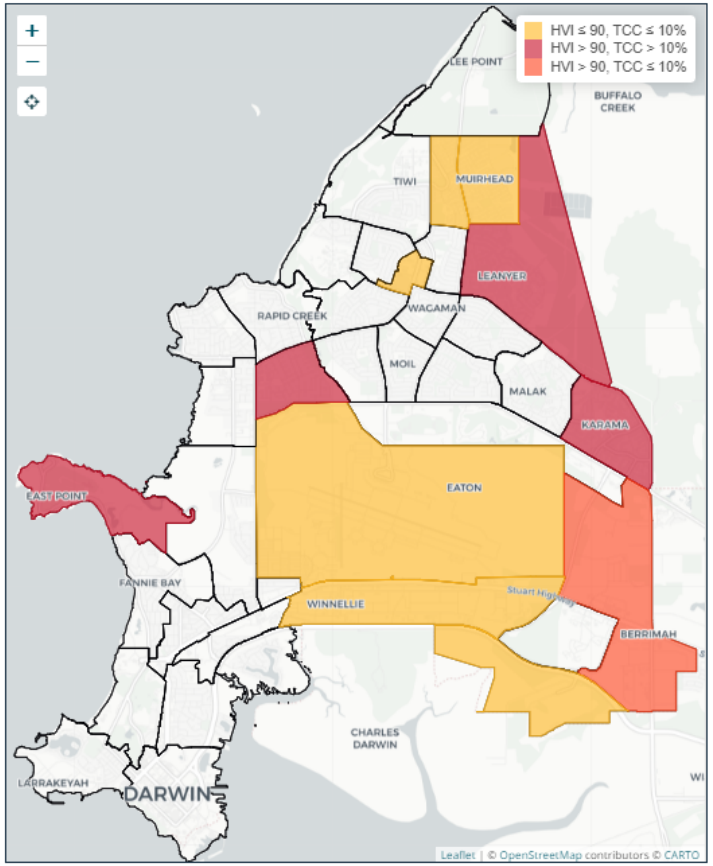
2016 -> 26.18 m^2



206 ha of TCC in 2016

	Valuation (thousand $ per year)
Pollution removal	25
Carbon storage	1,157
Avoided stormwater runoff	88
Annual flows of ecosystem services	**1,270**
Building energy savings	In progress (3x Canberra's annual flows)
Land rate premium	In progress(4x Canberra's annual flows)
Avoided heat morbidity	In progress (<1% Canberra's annual flows)

○ Base map ○ Urban heat ○ Tree cover ○ Vulnerability ● Combined



Click on a suburb on the map to explore at the mesh block level.

Combining heat mitigation indicators

The map to the left indicates regions with low tree canopy cover (TCC) and high vulnerability (HVI), as well as regions where low TCC and high HVI intersect. Interact with the sliders to adjust the cut off values for low TCC and high HVI:

Low TCC cut off (%) 0 — 10 — 30

High HVI cut off 0 — 90 — 100

Targeted heat mitigation by suburb for Darwin

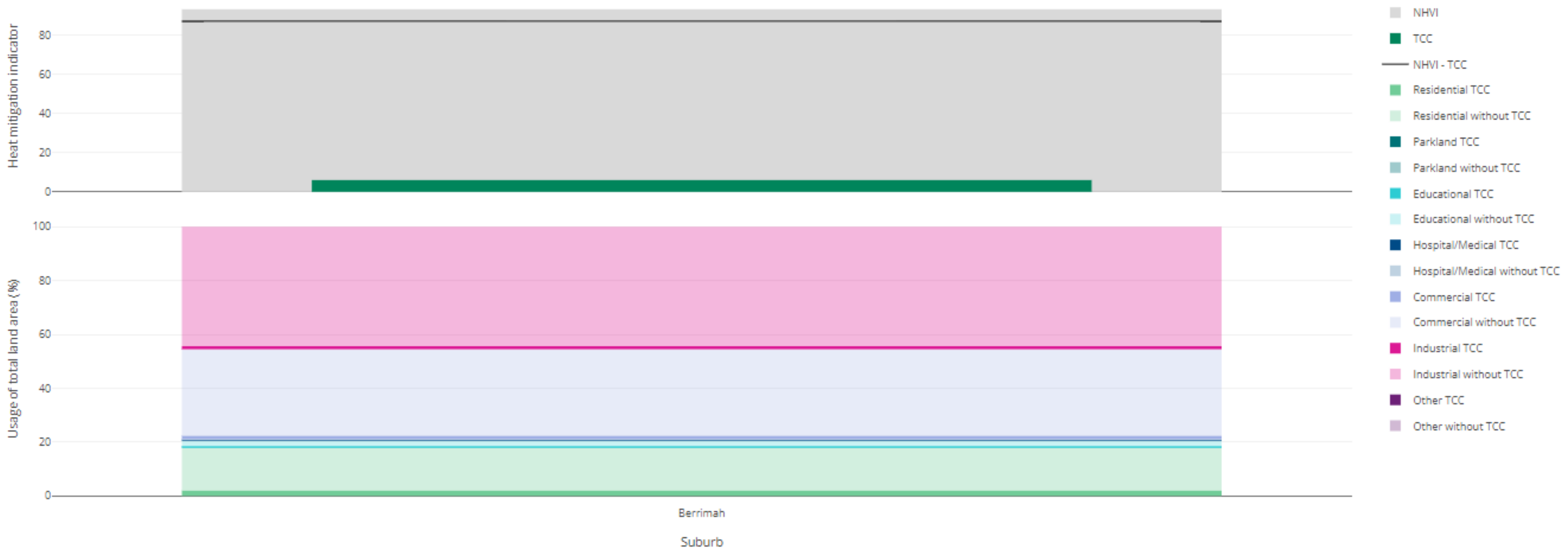
The following charts consider only those suburbs where low TCC and high HVI intersect.

The first chart visualises heat mitigation indicators HVI, TCC and HVI - TCC. Urban communities with high HVI should be prioritised for heat mitigation measures. Those suburbs with low percentage TCC may be prime targets for reducing heat vulnerability through urban greening. The difference between these two measures, HVI - TCC, may be used to identify vulnerable suburbs suitable for urban greening initiatives.

The second chart visualises each suburb's land area by TCC and land use zone. An area with low TCC may be a prime target for urban greening. however, built up industrial and commercial land use zones are likely to have less capacity for such initiatives than zones dedicated to parkland or residential land use.

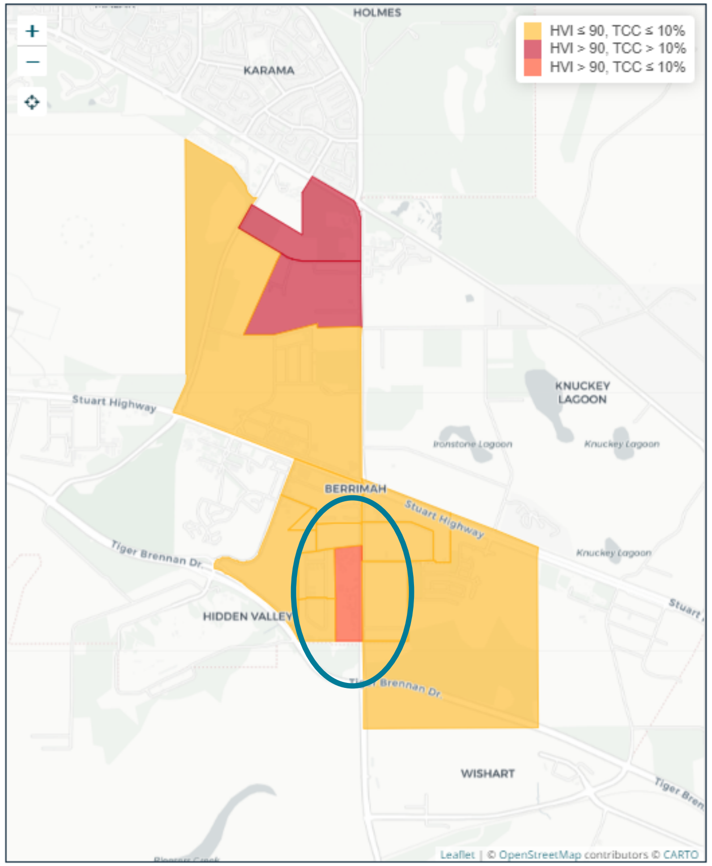
Suburbs ordered by

○ HVI (high to low) ○ TCC (low to high) ● HVI - TCC (high to low)



Darwin Living Lab   Home   Heat mitigation   Urban trees

Base map   Urban heat   Tree cover   Vulnerability   Combined



Click on a meshblock on the map to return to the suburb level view.

Combining heat mitigation indicators

The map to the left indicates regions with low tree canopy cover (TCC) and high vulnerability (HVI), as well as regions where low TCC and high HVI intersect. Interact with the sliders to adjust the cut off values for low TCC and high HVI:

Low TCC cut off (%) 0 10 80

High HVI cut off 0 90 100

Targeted heat mitigation by mesh block for Berrimah

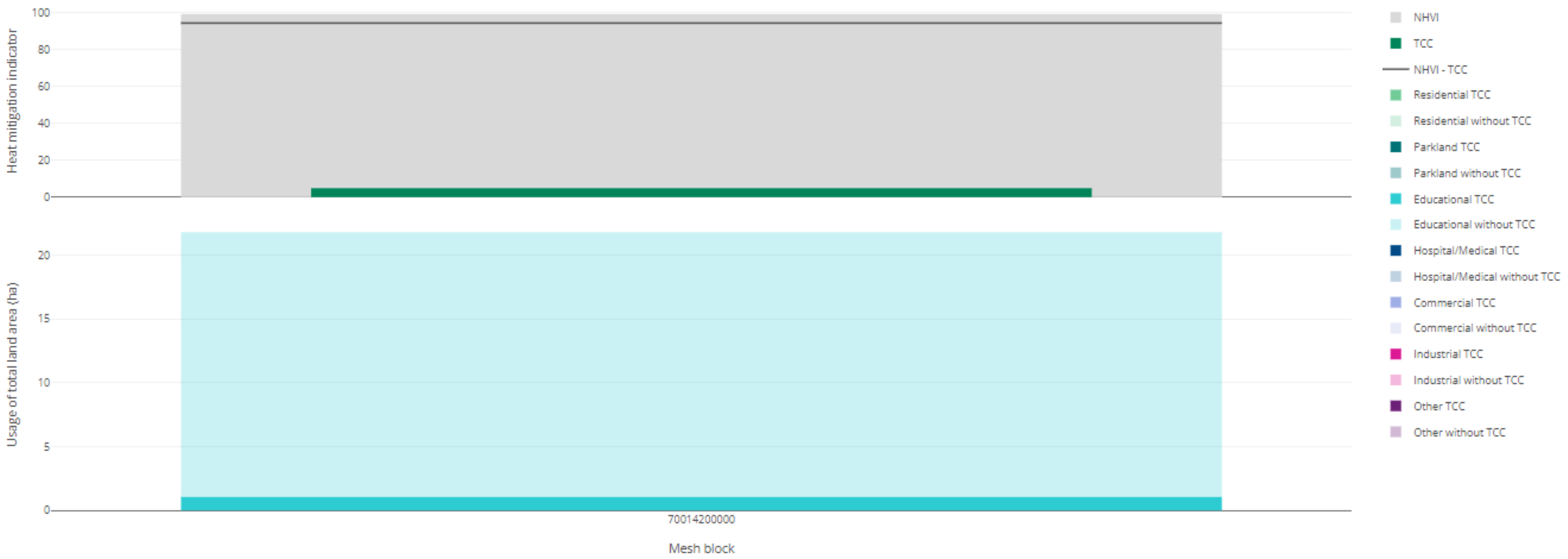
The following charts consider only those mesh blocks where low TCC and high HVI intersect.

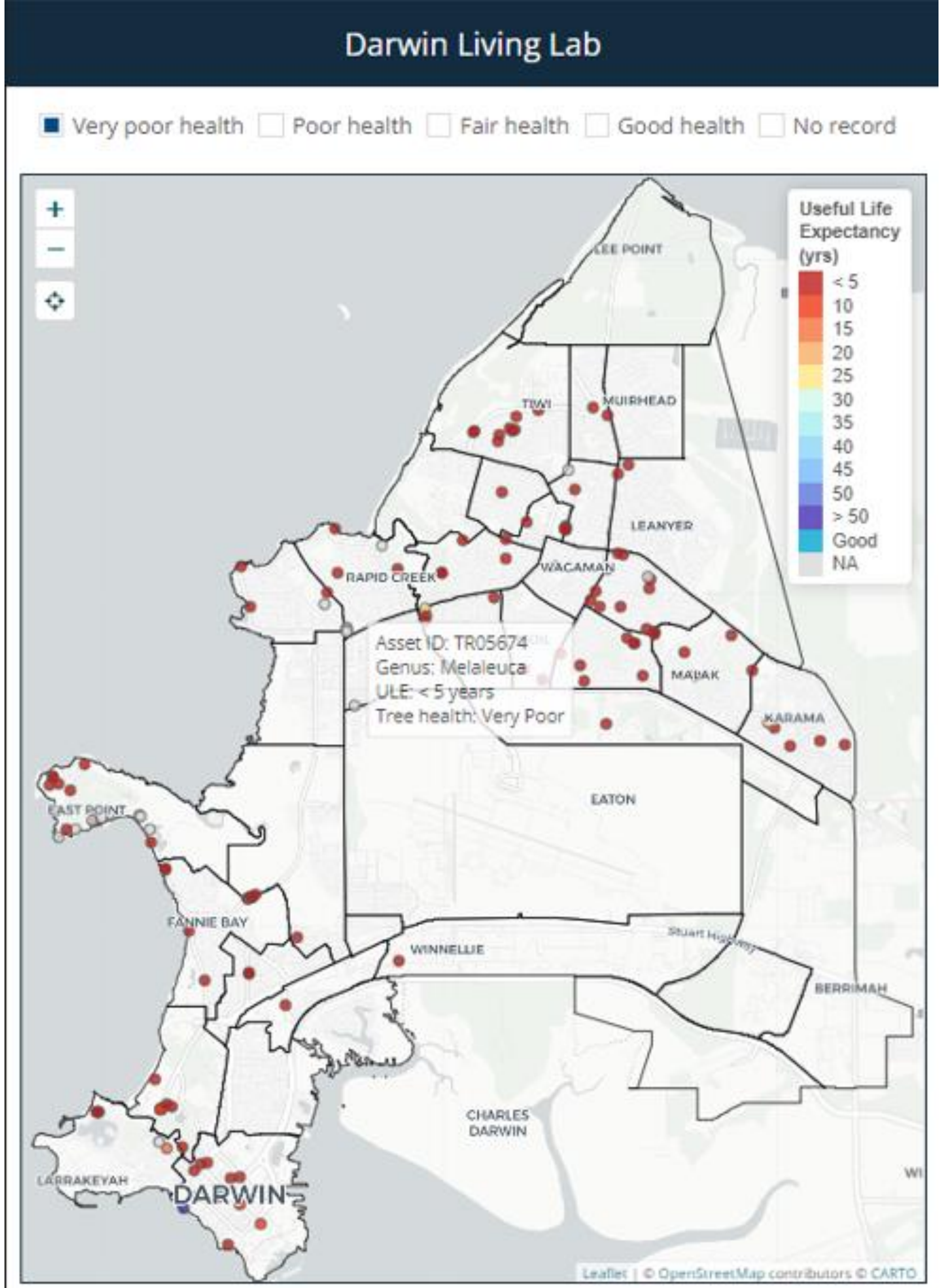
The first chart visualises heat mitigation indicators HVI, TCC and HVI - TCC. Urban communities with high HVI should be prioritised for heat mitigation measures. Those mesh blocks with low percentage TCC may be prime targets for reducing heat vulnerability through urban greening. The difference between these two measures, HVI - TCC, may be used to identify vulnerable mesh blocks suitable for urban greening initiatives.

The second chart visualises each mesh block's land area by TCC and land use zone. An area with low TCC may be a prime target for urban greening. however, built up industrial and commercial land use zones are likely to have less capacity for such initiatives than zones dedicated to parkland or residential land use.

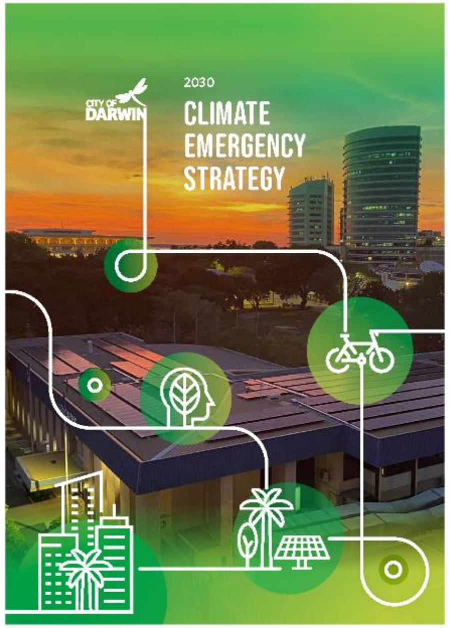
Mesh blocks ordered by

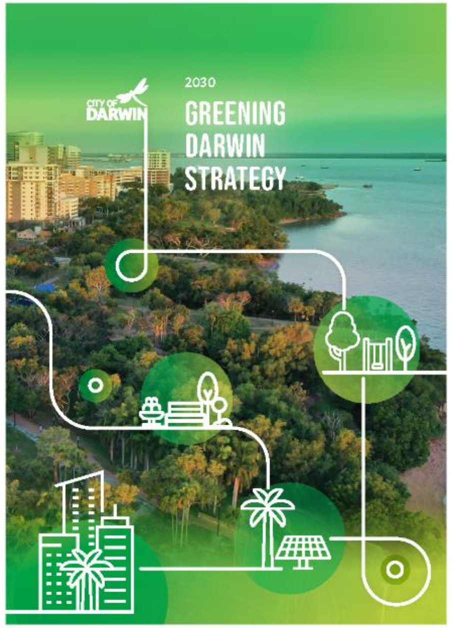
HVI (high to low)   TCC (low to high)   HVI - TCC (high to low)

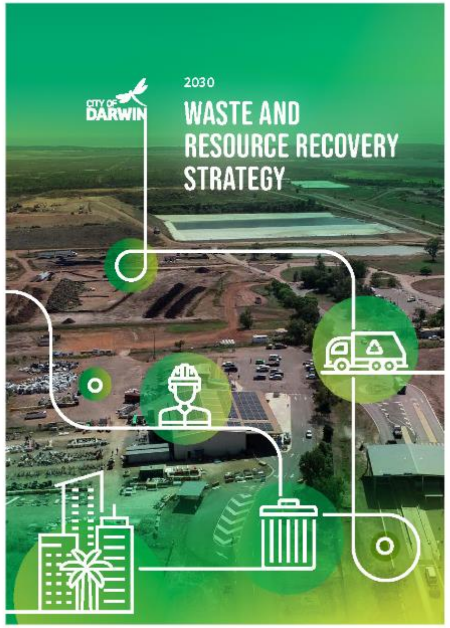



Darwin Living Lab
Very poor health
Poor health
Fair health
Good health
No record
Useful Life Expectancy (yrs)
< 5
10
15
20
25
30
35
40
45
50
> 50
Good
NA
LEE POINT
TIWI
MUIRHEAD
LEANYER
WAGAMAN
RAPID CREEK
MALAK
KARAMA
Asset ID: TR05674
Genus: Melaleuca
ULE: < 5 years
Tree health: Very Poor
EATON
EAST POINT
FANNIE BAY
WINNELLIE
Stuart Highway
BERRIMAH
CHARLES DARWIN
LARRAKEYAH
DARWIN
Leaflet | © OpenStreetMap contributors © CARTO

Supporting city level decisions.







CLIMATE

GREENING

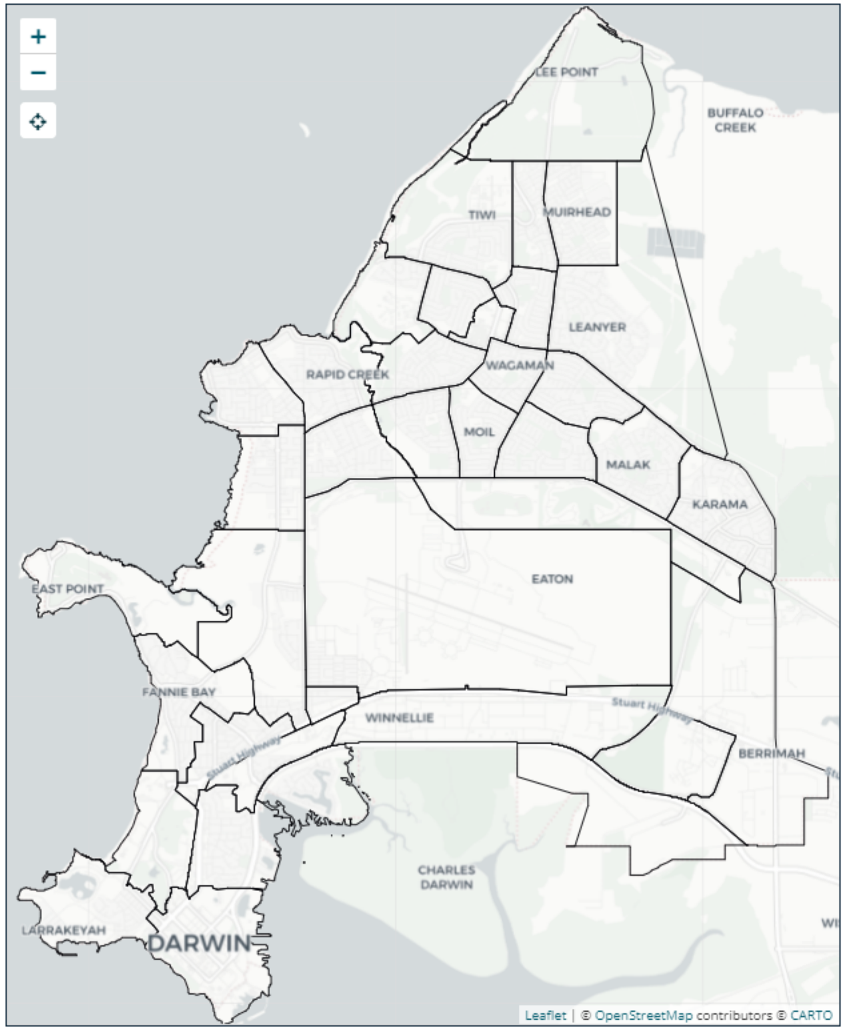
WASTE AND RESOURCE RECOVERY

Questions?

Land and Water

Ray Marcos Martinez
mar77v@csiro.au

Base map Urban heat Tree cover Vulnerability Combined



Heat mitigation

An urban heat island (UHI) is an urban area that is warmer than the surrounding countryside mainly as a result of solar radiation that is absorbed into building materials and hard paved surfaces during the day. This stored heat is then released slowly at night, reducing night time cooling relief after a hot day. Waste heat from sources such as factories, vehicles and air-conditioners are secondary contributors to the UHI.

Higher urban temperatures can affect human health, air quality and the level of resource use. Certain groups of people, such as those who are elderly, very young, or have certain mental or physical health conditions can be more sensitive to high temperatures in their environment. People in low socioeconomic circumstances are also more vulnerable if high costs restrict their ability to cool their homes.

Urban heat can be mitigated in a number of ways; reducing the amount of waste heat, increasing the use of vegetation and water, using 'cool' building materials and installing shade structures. These interventions provide cooling benefits through shade, evaporation, evapotranspiration, increasing reflectivity and emittance of materials and by channelling breezes.

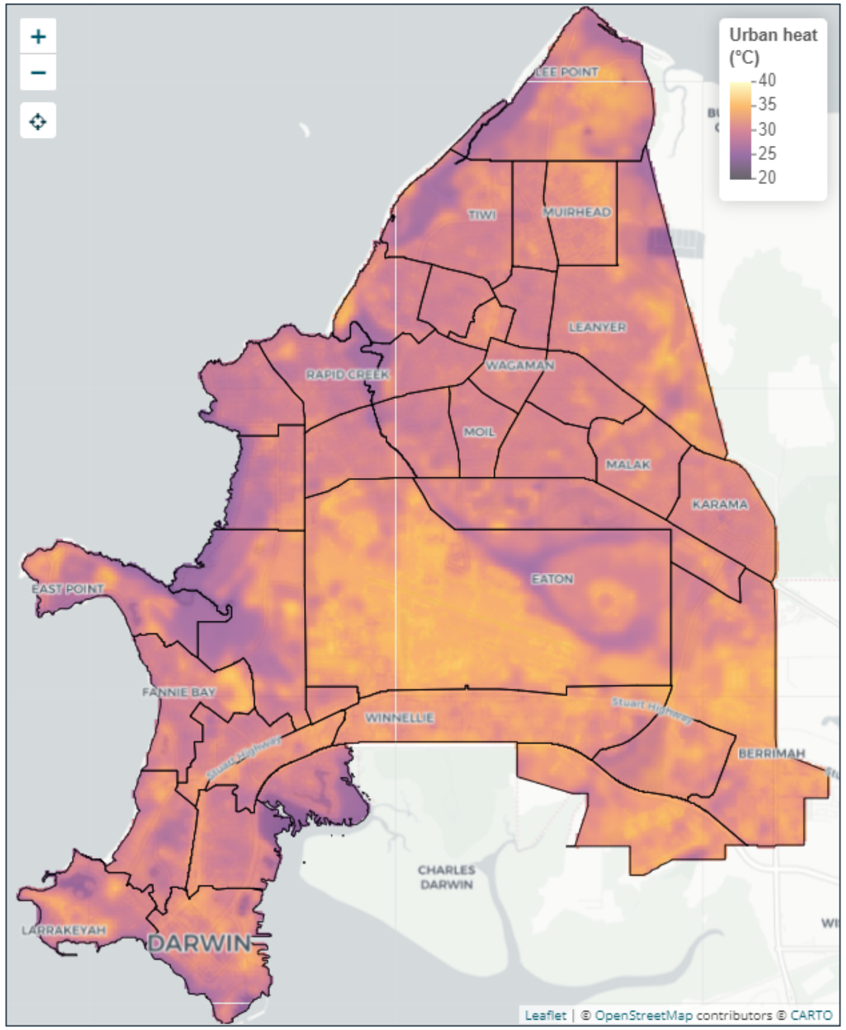
Identifying areas that have high heat exposure, little vegetation and tree canopy cover and high heat-related population vulnerability can assist with prioritising areas for urban heat mitigation actions.

Here, urban heat is represented by the temperature of surfaces, like roofs, roads and tree canopies that have been measured using satellite remote sensors. While there is not always a direct relationship between surface- and air-temperatures, air-temperature hotspots often occur where there are high surface temperatures.

Interact with the selection buttons above the map to explore land surface temperature, summaries of tree canopy cover, and information about socioeconomic disadvantage collected from multiple open sources or provided by Darwin Living Lab partners.

Darwin Living Lab   Home   Heat mitigation   Urban trees

Base map   Urban heat   Tree cover   Vulnerability   Combined

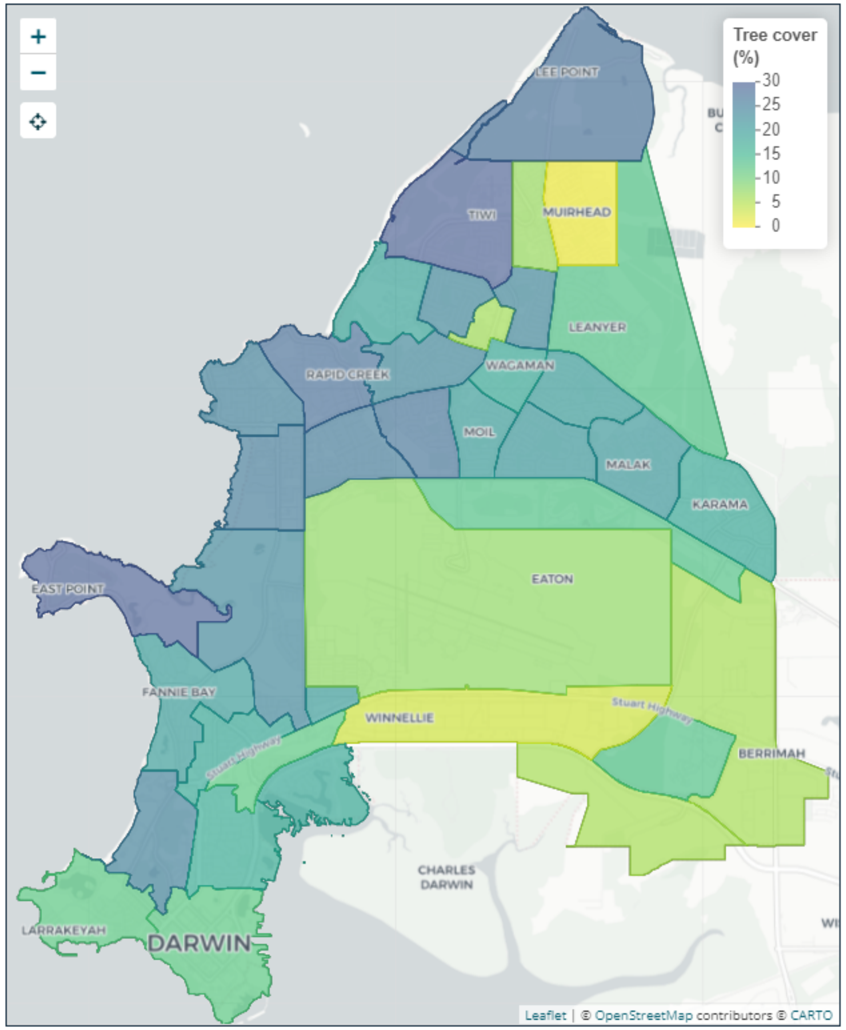


Click on a suburb on the map to explore at the mesh block level.

Urban Heat

The severity of heat experienced in cities during hot weather varies across the urban landscape. Areas with a high proportion of trees, irrigated vegetation and water tend to have cooler temperatures during the day than areas with a large amount of impervious surface cover (e.g. roofs and paving). Seasonal changes can affect the temperature of unirrigated grass, with green grass being much cooler than dry sparse grass on a hot day. The land surface temperature (LST) map to the left can be used to help prioritise activities to mitigate high urban temperatures and to evaluate which urban features influence the magnitude of those temperatures.

Base map | Urban heat | Tree cover | Vulnerability | Combined



Click on a suburb on the map to explore at the mesh block level.

Urban vegetation

Vegetation provides a range of benefits that improve human and environmental health in cities (Lin et al. 2016). It creates cooler urban temperatures, lowers heat-related health risk and reduces the energy required for air-conditioning. Vegetation enhances quality of life by increasing psychological wellbeing and by providing opportunities to experience nature. It provides many other benefits too, such as flood mitigation and noise attenuation. Vegetation also has costs associated with planting and maintenance and it can be challenging to grow healthy vegetation in cities. Trees are a major component of the green infrastructure in cities, providing shade and localised cooling, habitat for animals, flood control and air pollution reduction. Trees along streets and in parks provide people with enjoyment and a way to connect with nature.

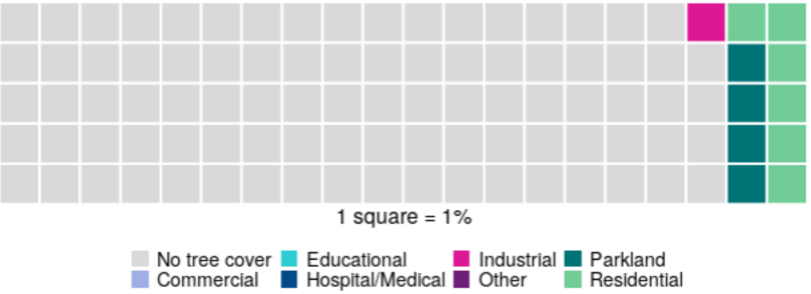
Tree canopy cover

Many cities have targets for urban greening. Knowing the amount of tree canopy cover (TCC) in an area can help cities to reach urban greening targets. Areas without TCC, such as roads, rooftops and paving are often impervious and contribute to the urban heat island. TCC within mesh block areas in Darwin are represented below.

Average TCC within mesh block areas in Darwin by major land use zone:

- 5% Commercial
- 12% Educational
- 9% Hospital/Medical
- 7% Industrial
- 2% Other
- 16% Parkland
- 14% Residential

Percentage of TCC within mesh blocks in Darwin:



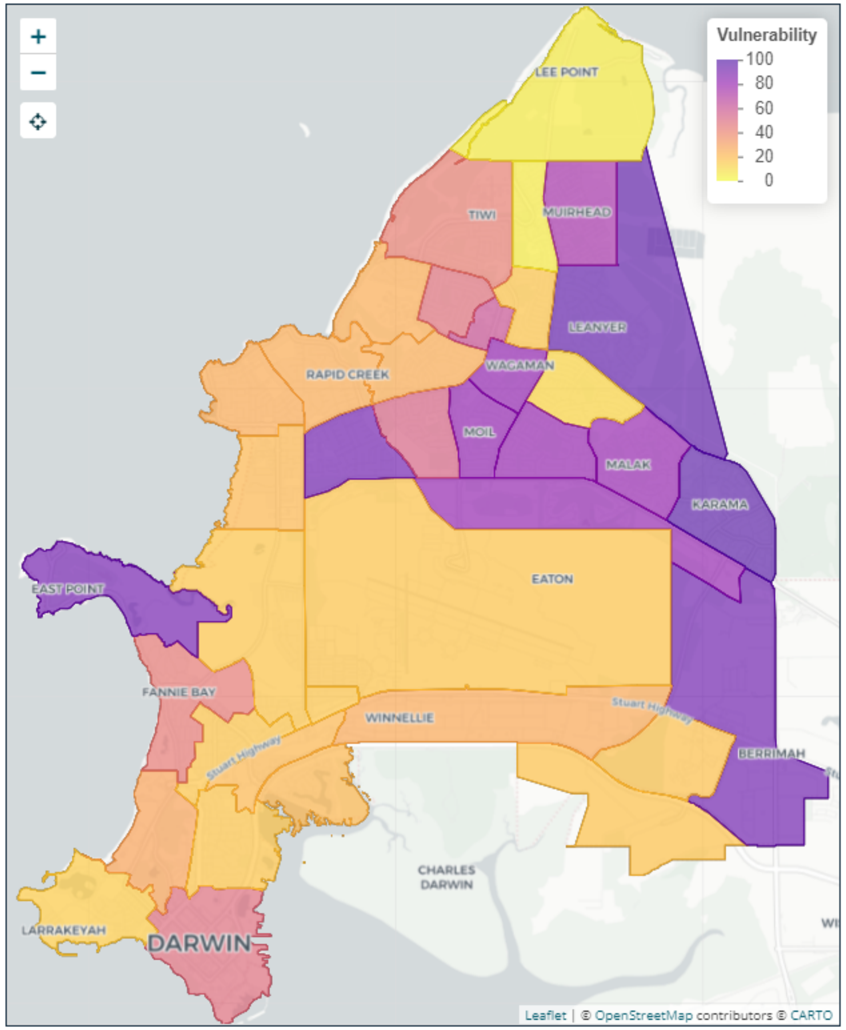
Tree canopy distribution across land uses

The amount of tree cover often varies by land-use type. For example, industrial areas tend to have large expanses of impervious surfaces, fewer trees, and higher surface temperatures. Similarly, higher density residential areas often fewer trees and higher surface temperatures than lower density suburban areas where there is more room for trees to grow.

Residential areas in Darwin have an average of 48% TCC. Some studies recommended that urban areas aim for at least 40% TCC overall, with 50% in suburban residential, 25% in urban residential, and 15% in central business districts (USDA, 2002).

Distribution of TCC within major land uses in Darwin:

Base map
Urban heat
Tree cover
Vulnerability
Combined



Click on a suburb on the map to explore at the mesh block level.

Heat Vulnerability Index (HVI)

The HVI identifies areas where populations are more vulnerable to the adverse effects of urban heat. It is a relative measure of heat-risk vulnerability and can be used to guide the prioritisation of areas for reducing heat vulnerability in urban communities. The HVI was calculated by overlaying indices of exposure, sensitivity and adaptive capacity to urban heat.

The following ABS 2016 Census variables (ABS, 2016b) were used to create the index:

- Heat-health risk: people who are "elderly" (65 years or older); "very young" (under 5 years old); "need assistance with core activities" (self-care, mobility or communication); or who identify as "Aboriginal and Torres Strait Islander".
- Economic resources available to a household: people who live in "public housing"; or who live in "low income households". Low-income households are often defined as those in the lowest 20% or 25% of income (ABS, 2017; ACOSS, 2011). The modified OECD equivalence scale is used by the ABS to reflect the economic resources available to a standardised household (ABS, 2017) and is adopted in this project. In this measure, the amount of disposable household income is adjusted for the number of people living in a household and the age of the occupants.

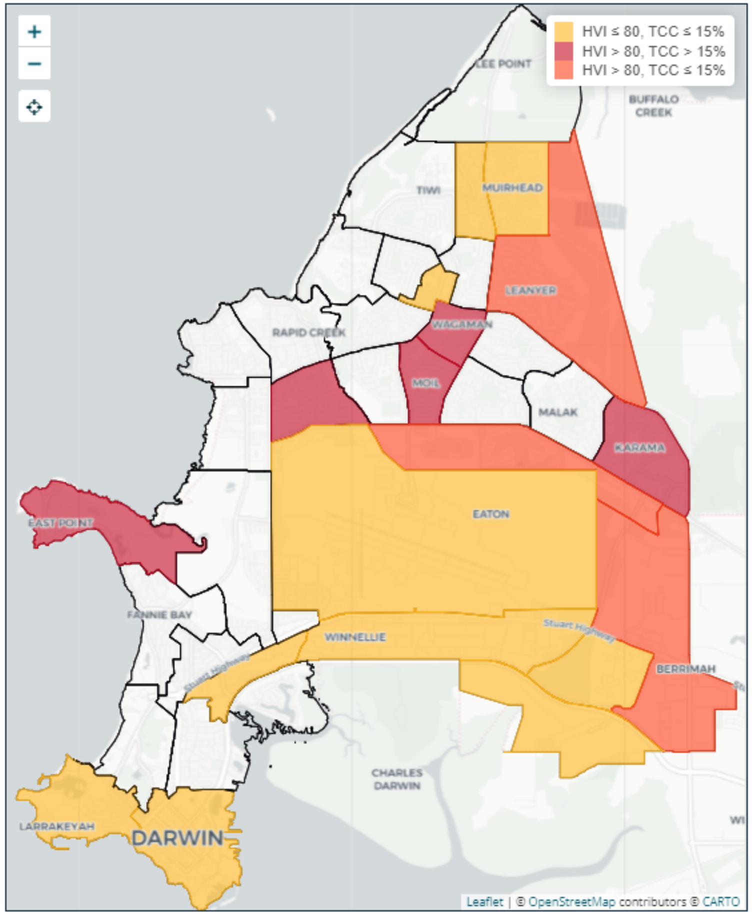
Based on the lowest 20–25% grouping, an equivalised income below $800 per week is defined as low-income in Darwin, which represents the lowest 24% of household incomes at the time of the Census in August 2016.

The number of people in each mesh block who satisfy each of these criteria was extracted using the ABS tool TableBuilder. Two factors were found to be highly correlated; the number of "elderly" people and those who "need assistance with core activities" (p=0.75), and the latter was dropped from further analyses.

To estimate potential exposure to higher temperatures, median dry season land surface temperature (LST) was calculated for each mesh block. While median mesh block LST is a coarse measure, it is indicative of relative exposure between mesh blocks. Median LST was calculated rather than mean as it removes bias associated with extreme values which may occur when there are mixed signals in the satellite imagery close to the coast. The HVI was calculated by first summing the number of people within each mesh block who satisfy the criteria for each of the five risk factors. This represents "units of risk". These mesh block values were then ranked and scaled from the highest (100) to the lowest (0) risk. The data were ranked because there is no a priori knowledge of the relative importance of an individual count, whereas raw counts would infer that a linear relationship existed. Ranking allows for a simple priority sorting.

Next, the median land surface temperatures of mesh blocks were ranked and scaled to create a heat exposure score from the hottest (100) to the coolest (0) mesh block. Again, ranks were used because there is no a priori relationship between LST values and the relative threat individual values generate. The ranked and scaled "units of risk" and "median LST" were multiplied and the product was ranked and scaled to create a neighbourhood heat-health vulnerability score, from the mesh blocks with the highest (100) to the lowest (0) vulnerability.

Base map Urban heat Tree cover Vulnerability Combined



Click on a suburb on the map to explore at the mesh block level.

Combining heat mitigation indicators

The map to the left indicates regions with low tree canopy cover (TCC) and high vulnerability (HVI), as well as regions where low TCC and high HVI intersect. Interact with the sliders to adjust the cut off values for low TCC and high HVI:

Low TCC cut off (%) 0 15 30

High HVI cut off 0 80 100

Targeted heat mitigation by suburb for Darwin

The following charts consider only those suburbs where low TCC and high HVI intersect.

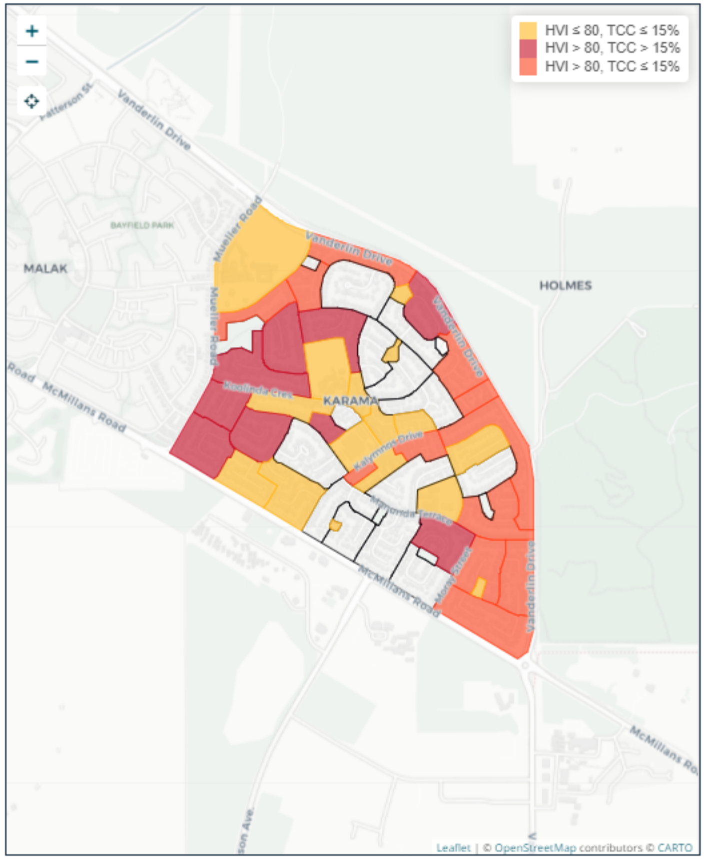
The first chart visualises heat mitigation indicators HVI, TCC and HVI - TCC. Urban communities with high HVI should be prioritised for heat mitigation measures. Those suburbs with low percentage TCC may be prime targets for reducing heat vulnerability through urban greening. The difference between these two measures, HVI - TCC, may be used to identify vulnerable suburbs suitable for urban greening initiatives.

The second chart visualises each suburb's land area by TCC and land use zone. An area with low TCC may be a prime target for urban greening. however, built up industrial and commercial land use zones are likely to have less capacity for such initiatives than zones dedicated to parkland or residential land use.

Suburbs ordered by

HVI (high to low) TCC (low to high) HVI - TCC (high to low)

Base map | Urban heat | Tree cover | Vulnerability | Combined



Click on a meshblock on the map to return to the suburb level view.

Combining heat mitigation indicators

The map to the left indicates regions with low tree canopy cover (TCC) and high vulnerability (HVI), as well as regions where low TCC and high HVI intersect. Interact with the sliders to adjust the cut off values for low TCC and high HVI:

Low TCC cut off (%) — 0, 15, 80

High HVI cut off — 0, 80, 100

Targeted heat mitigation by mesh block for Karama

The following charts consider only those mesh blocks where low TCC and high HVI intersect.

The first chart visualises heat mitigation indicators HVI, TCC and HVI - TCC. Urban communities with high HVI should be prioritised for heat mitigation measures. Those mesh blocks with low percentage TCC may be prime targets for reducing heat vulnerability through urban greening. The difference between these two measures, HVI - TCC, may be used to identify vulnerable mesh blocks suitable for urban greening initiatives.

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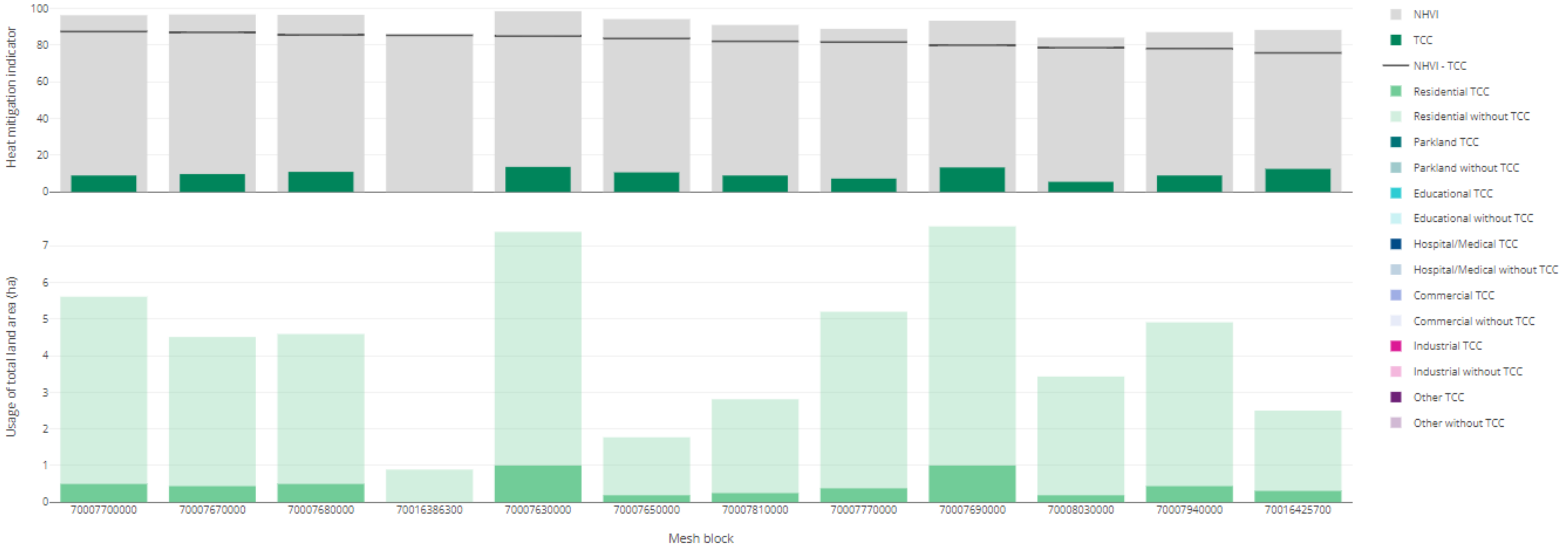
Mesh blocks ordered by

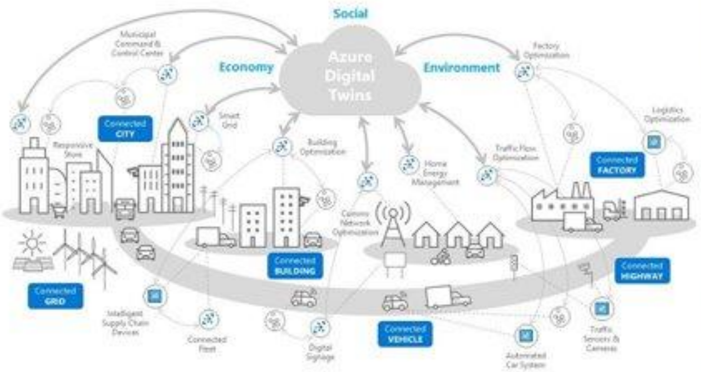
HVI (high to low) | TCC (low to high) | HVI - TCC (high to low)



What is a digital twin?

Digital Twin Starter Pack

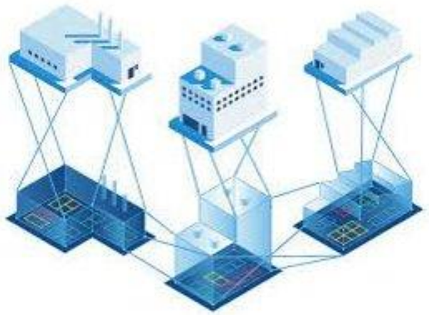
Overproduced marketing graphics



Icons and arrows in Illustrator

Renderings with ghostly digital stuff

Lots of digital lens flare *(flair)*



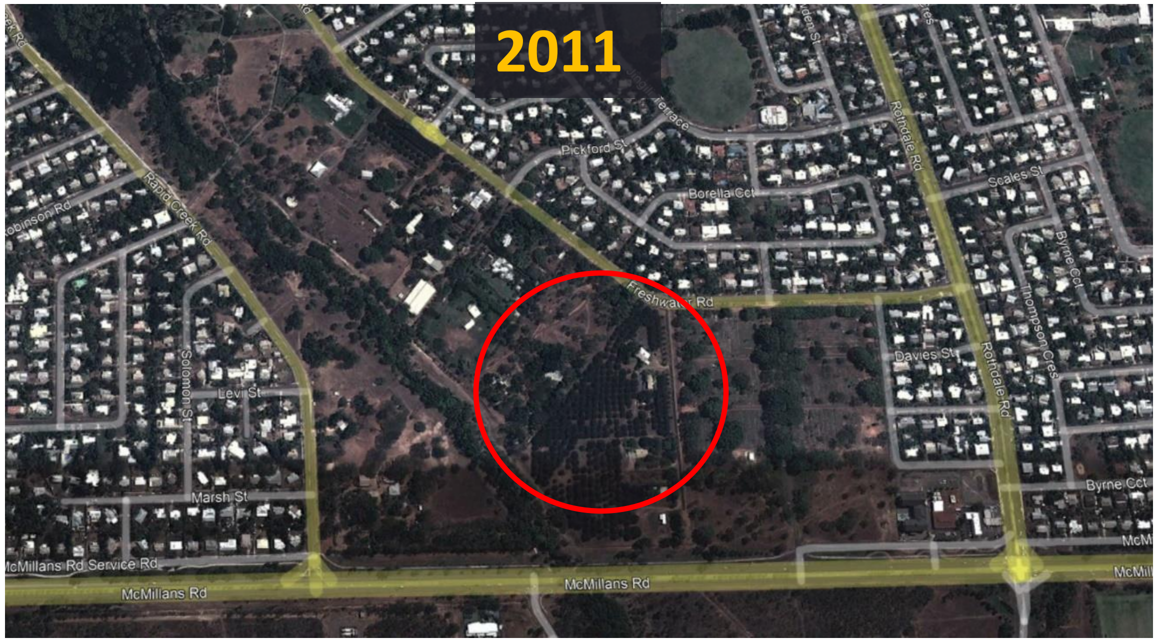
????

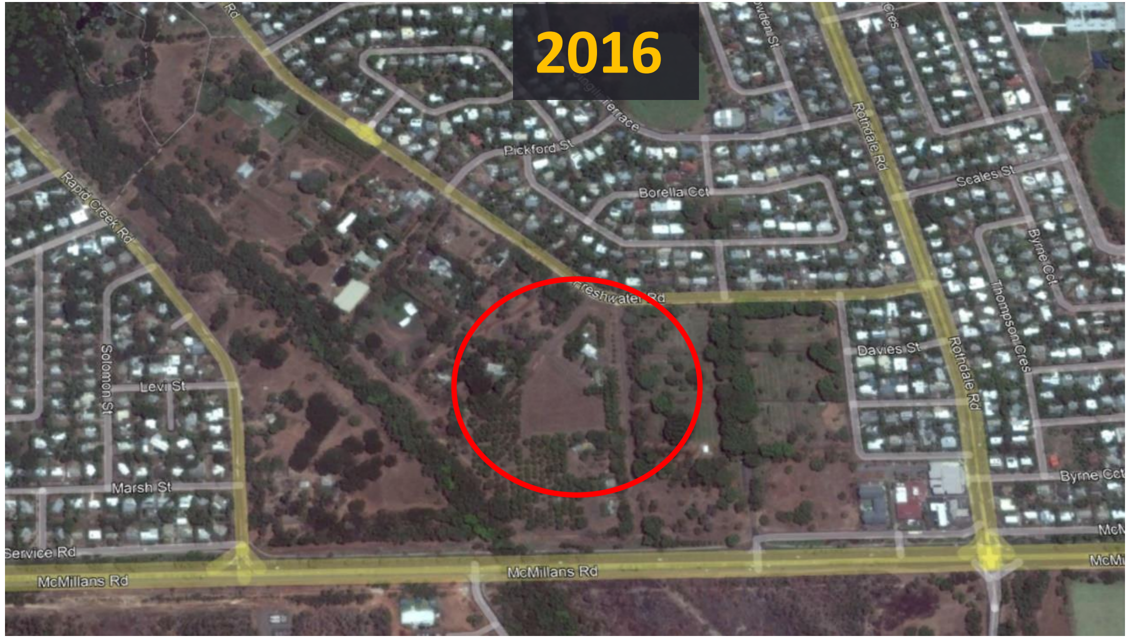
Some dude holding a digital thing

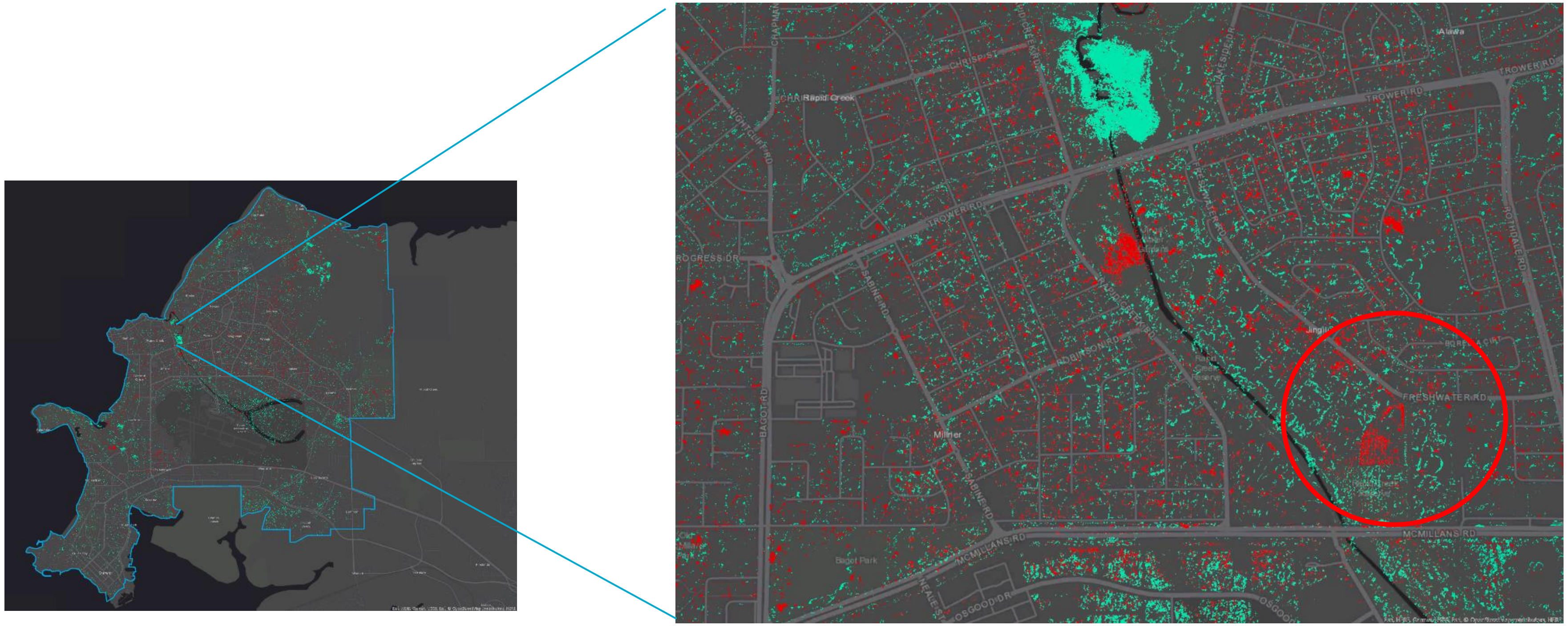
Source: Nathan Miller @archinate (Nitter)

Science and data driven models of urban processes.

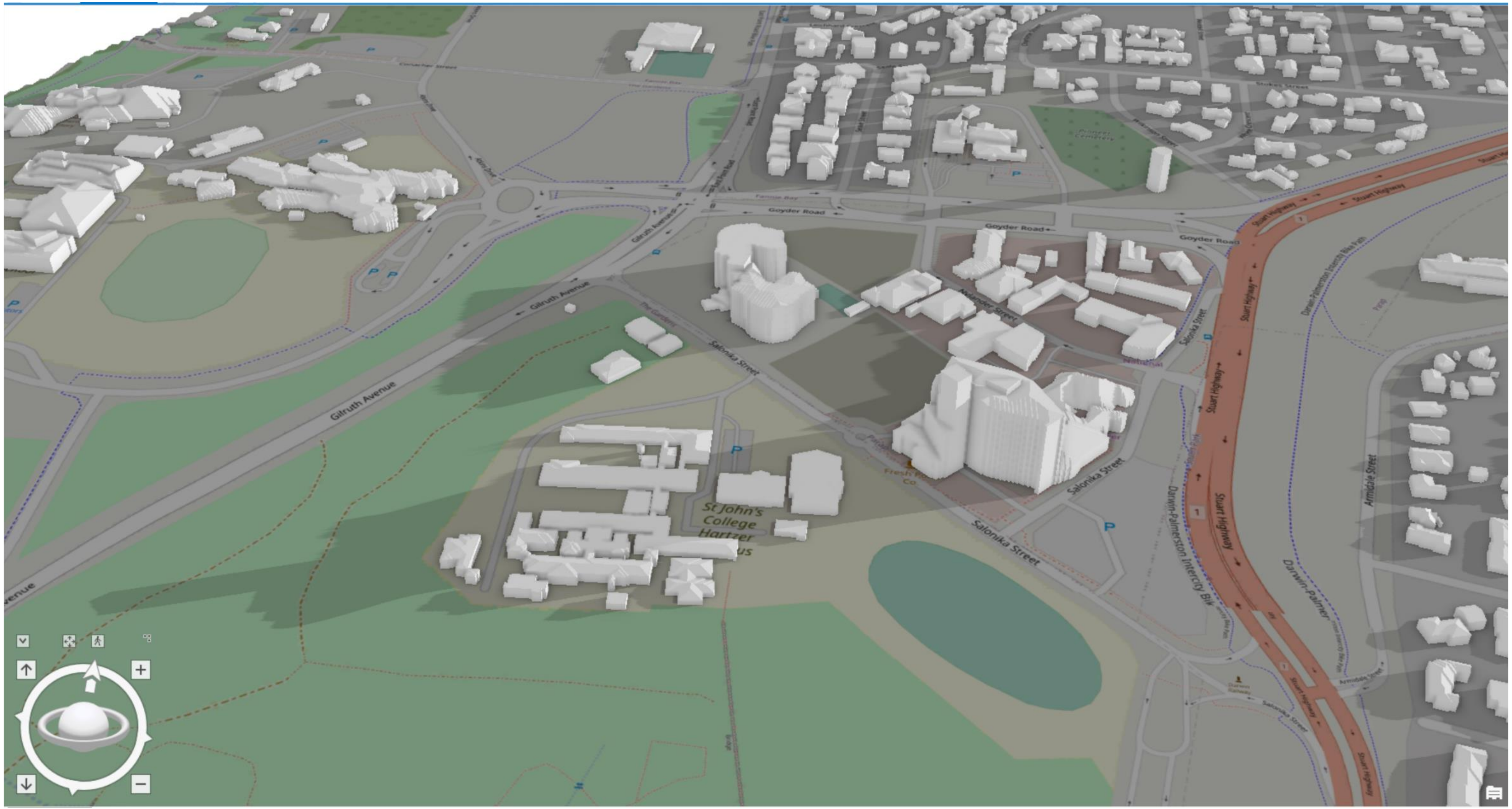
Long range 3D laser data (Shaun Levick and Jodie Hayward)


2011
Pickford St
Borella Cct
Scales St
Freshwater Rd
Davies St
Levi St
Marsh St
Solomon St
Rapid Creek Rd
Byrne Cct
McMillans Rd Service Rd
McMillans Rd


2016
Pickford St
Borella Cct
Scales St
Freshwater Rd
Davies St
Levi St
Marsh St
Solomon St
Rapid Creek Rd
Byrne Cct
Service Rd
McMillans Rd


TROWER RD
FRESHWATER RD
MCMILLANS RD
Millner

Science and data driven models of urban processes.



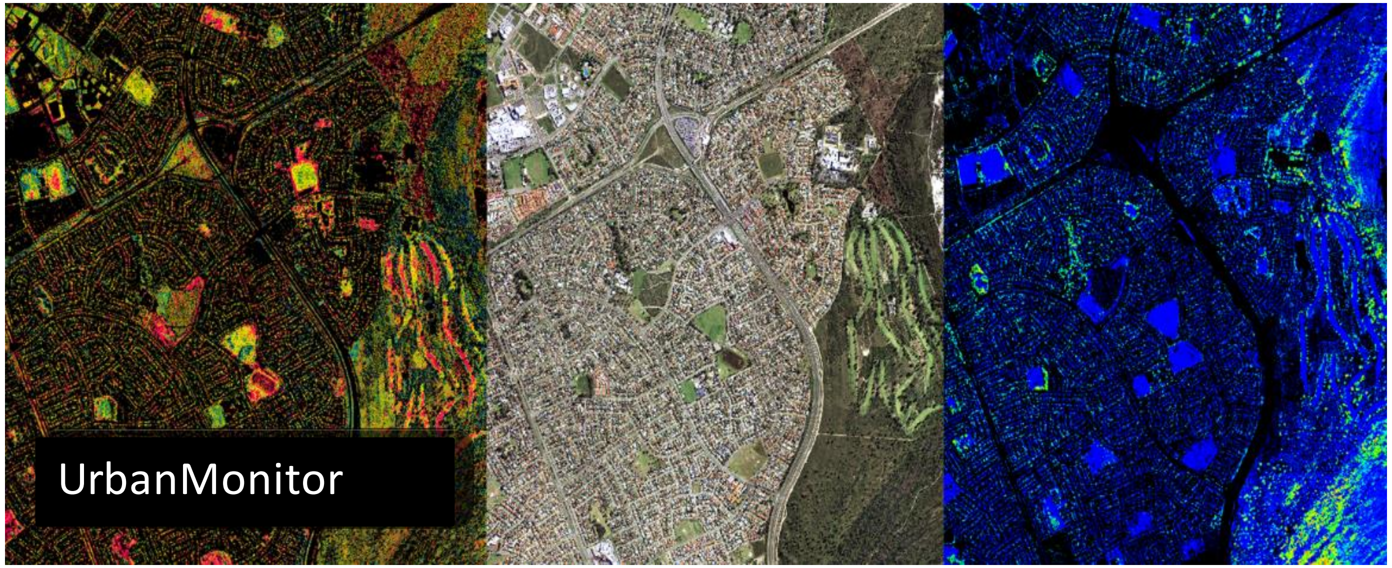
Science and data driven models of urban processes.

- Surveying of Darwin residents about how, when and why they use and value urban green spaces,
- Investigating spatial trends of heat and air quality across Darwin using a network of environmental **sensors**.
- Long range 3D laser data for high resolution analysis of tree growth.

TCC in 2016	206	hectares	
Biophysical flows			**Valuation** (thousand $ per year)
Pollution removal	11	metric tonnes /year	25
Carbon storage	50,625	metric tonnes /year	1,157
Carbon sequestration	828	metric tonnes /year	19
Avoided stormwater runoff	39	thousand cubic meters/year	88
Annual flows of ecosystem services			**1,289**
Building energy savings		In progress (3x Canberra's annual flows)	
Land rate premium		In progress(4x Canberra's annual flows)	
Avoided heat morbidity		In progress (<1% Canberra's annual flows)	

Australia's National Science Agency

In Darwin we are co-developing urban sustainability science solutions that are scalable, flexible, cost-effective with potential to be a global benchmark.


UrbanMonitor


NSW Spatial digital twin