GISail RMIT

Web-Based Heat Vulnerability Index Toolkit for Local Governments

- Rapid HVI Computing and Technical Considerations

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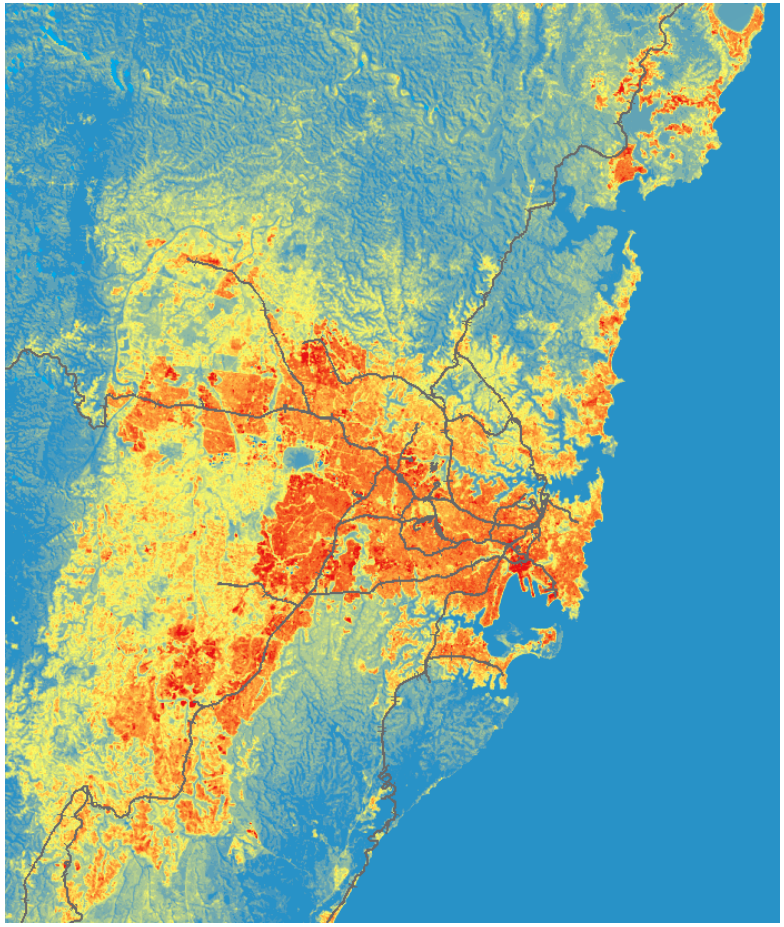
What's next...

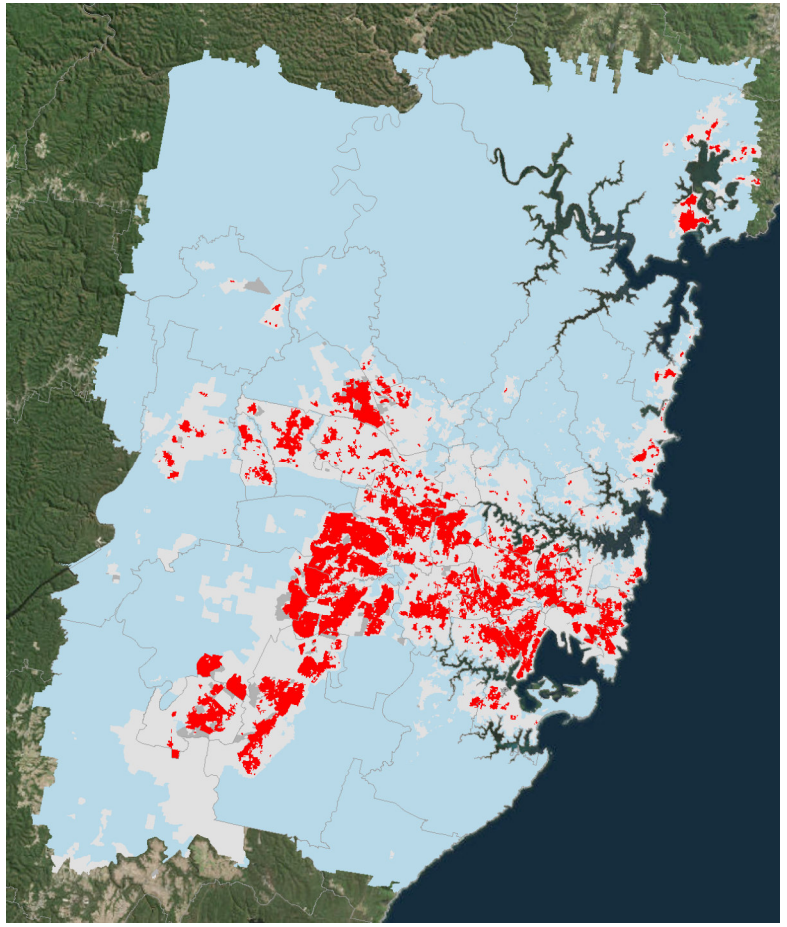
RMIT UNIVERSITY

Content

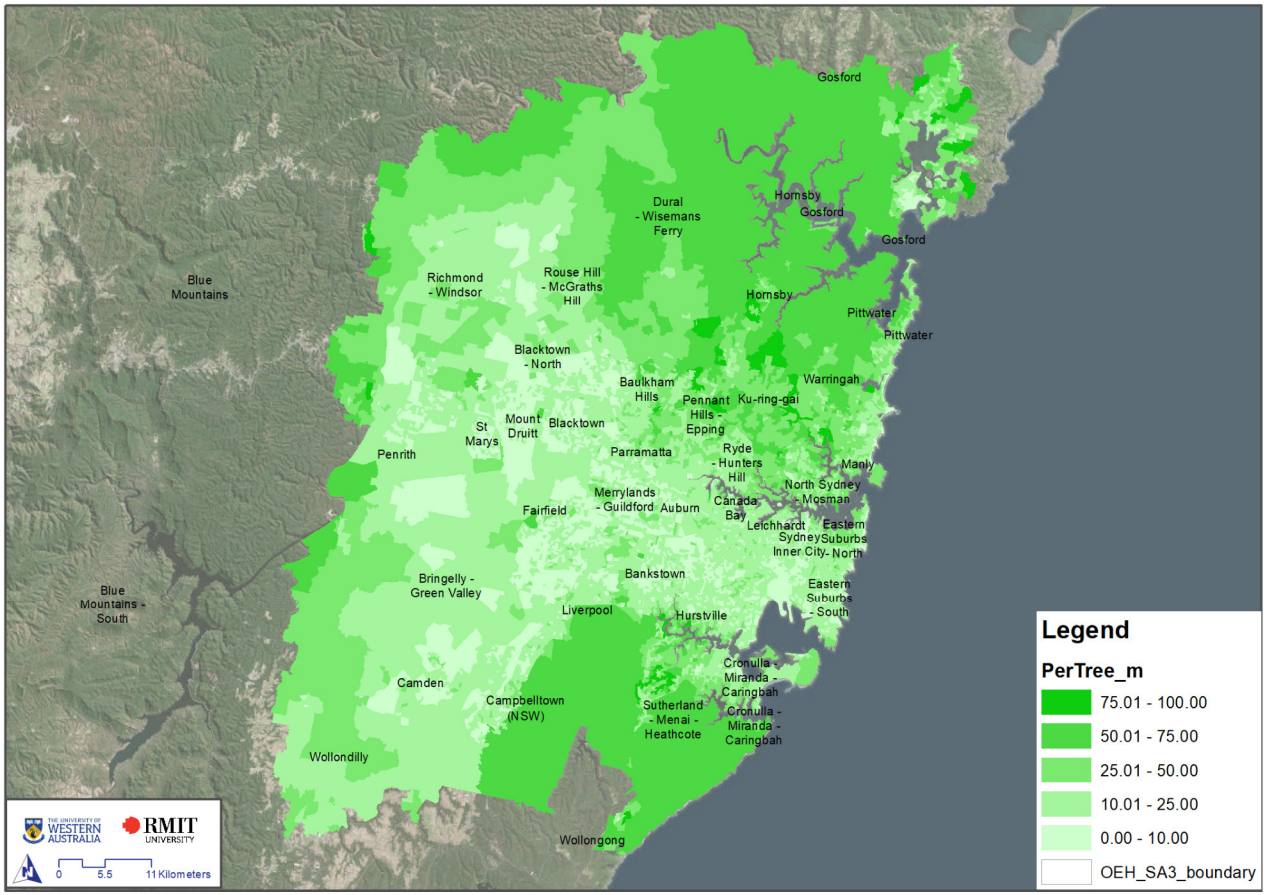
- Background and Aims
- Conceptual Framework
- Toolkit Development and Demo
- Case Study and Applications

Where are the hotter areas in Greater Sydney?



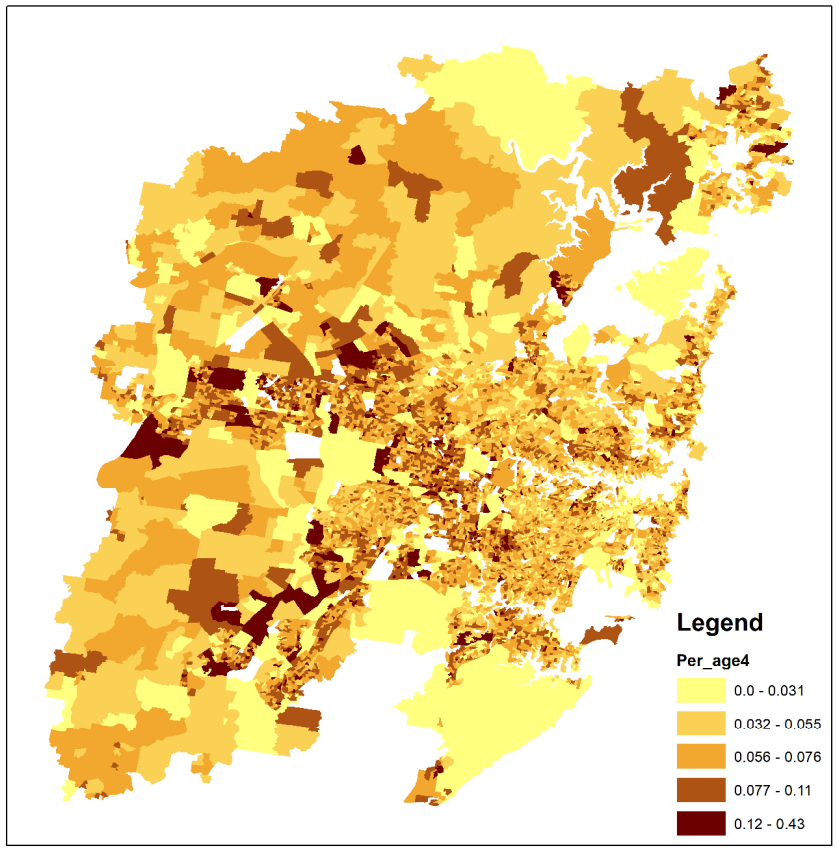


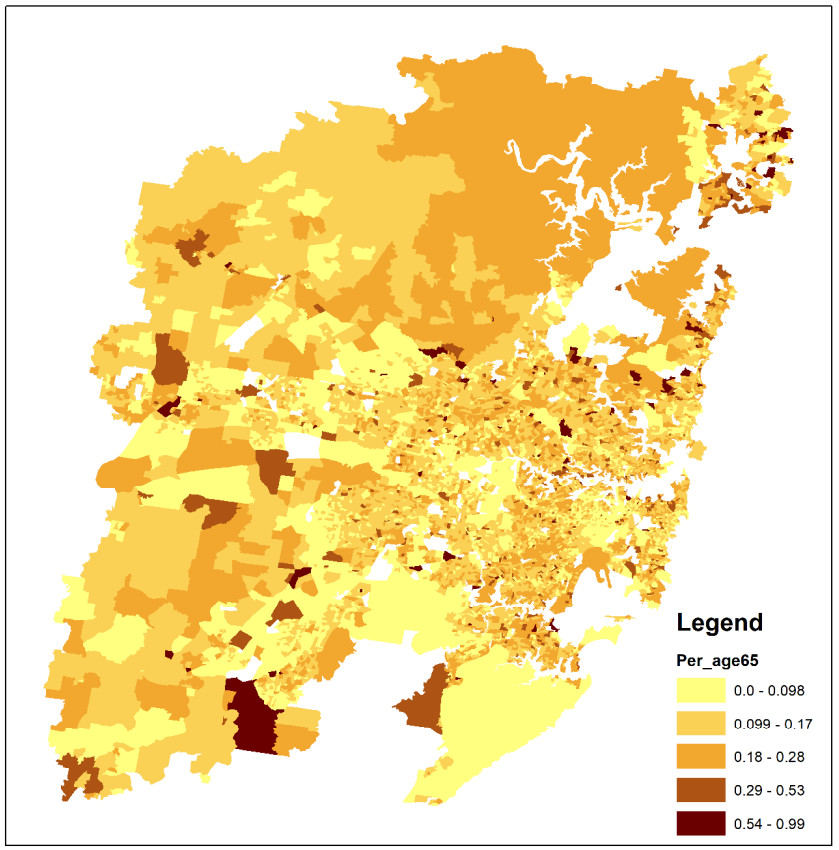
Where are the greener areas in Greater Sydney?



Cool down the heat?

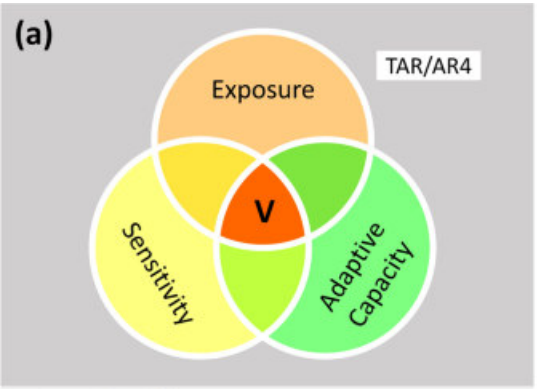
Where are the at-risk population groups in Greater Sydney?





More sensitive to heat? Less capable to respond to heat?

Data: Indicators and justification



Vulnerability (V) (IPCC 2007, p. 883)
"The degree to which a system is susceptible to, and [**or** in IPCC 2001] unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation [**climate variation** in IPCC 2001] to which a system is **exposed**, its **sensitivity**, and its **adaptive capacity**." (bold emphasis added)

Exposure (IPCC 2001, p. 987)
"The nature and degree to which a system is exposed to significant climatic variations."
(not defined in IPCC 2007)

Sensitivity (IPCC 2007, p. 881)
"The degree to which a system is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea-level rise)."

Adaptive capacity (IPCC 2007, p. 869)
"The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences."

	Indicators	Justifications	
Exposure to heat	**A:** Mean UHI based on meshblocks	provides an exposure indicator for heat.	+
Heat Sensitivity	**B:** % vegetation cover	provides a sensitivity indicator for the retention of heat in the urban environment.	−
	C: % roads (road corridor polygon dataset)	provides a sensitivity indicator for the retention of heat in the urban environment.	+
	D: Population density (persons per square km)	prevents the generation of spatial biases induced by very large/small census tracts. high number corresponding with a high sensitivity score, as denser of population are more sensitive to heat related health complications.	+
	E: %of over 65 years old person	with high number corresponding with a high sensitivity score, as elderly people are more sensitive to heat related health complications.	+
	F: %of 4 and below person	with high number corresponding with a high sensitivity score, as very young kids are more sensitive to heat related health complications.	+
	G: %of persons need care	with high number corresponding with a high sensitivity score, as more persons needing care indicating more sensitive to heat related health complications	+
Adaptive capability	**H:** (SEIFA-IEO) Education score	as more advantaged populations have more resources to respond to heat.	−
	I: SEIFA-IRSD (Economic score)	as more advantaged populations have more resources to respond to heat.	−

Aim and objectives

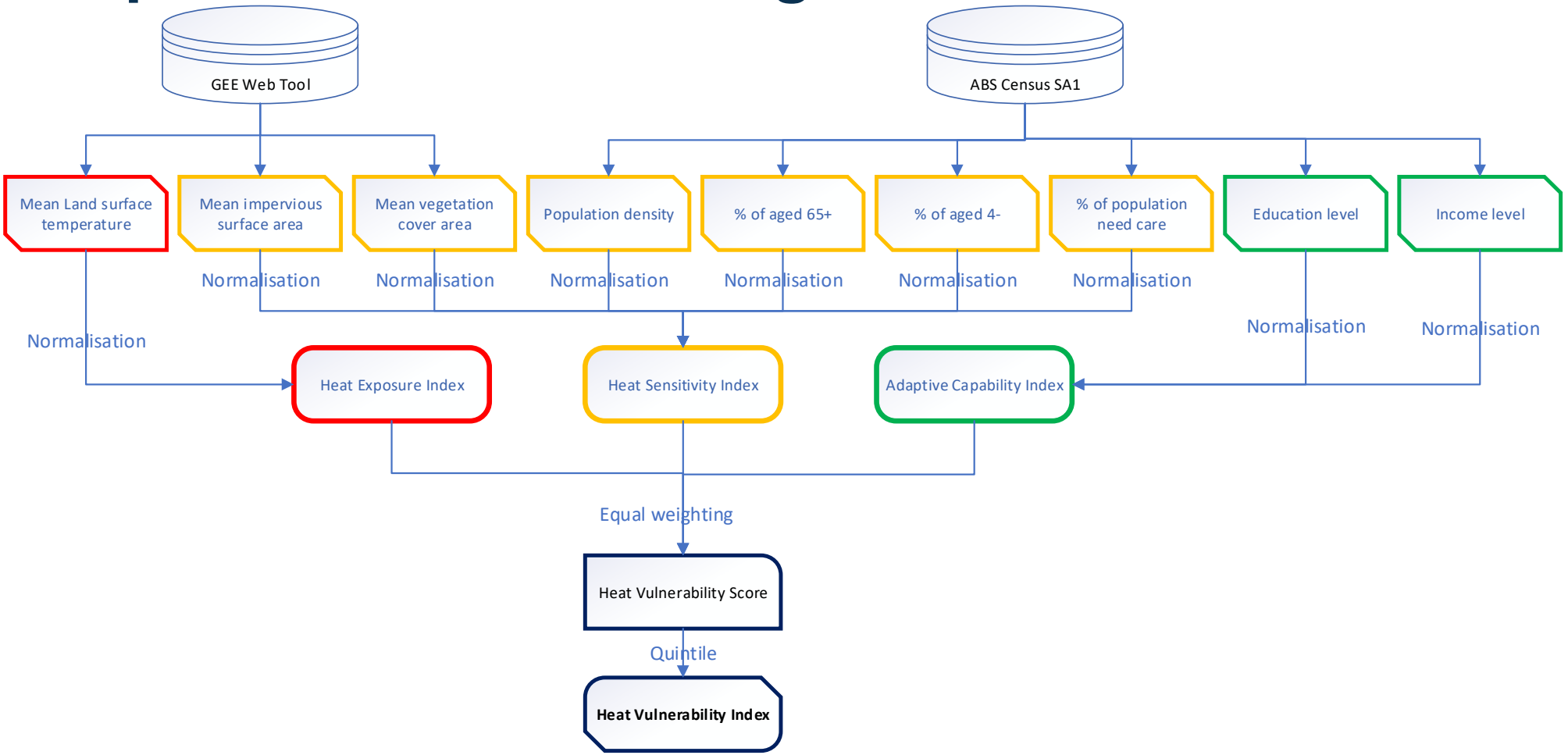
To establish a first nation-wide, dynamic and interactive heat vulnerability assessment toolkit, so the indicators and tools can be used to support spatial planning applications.

The objectives are to:

1. Develop a web app to retrieve land surface temperature and landcover indicators via Google Earth Engine (GEE) cloud platform;

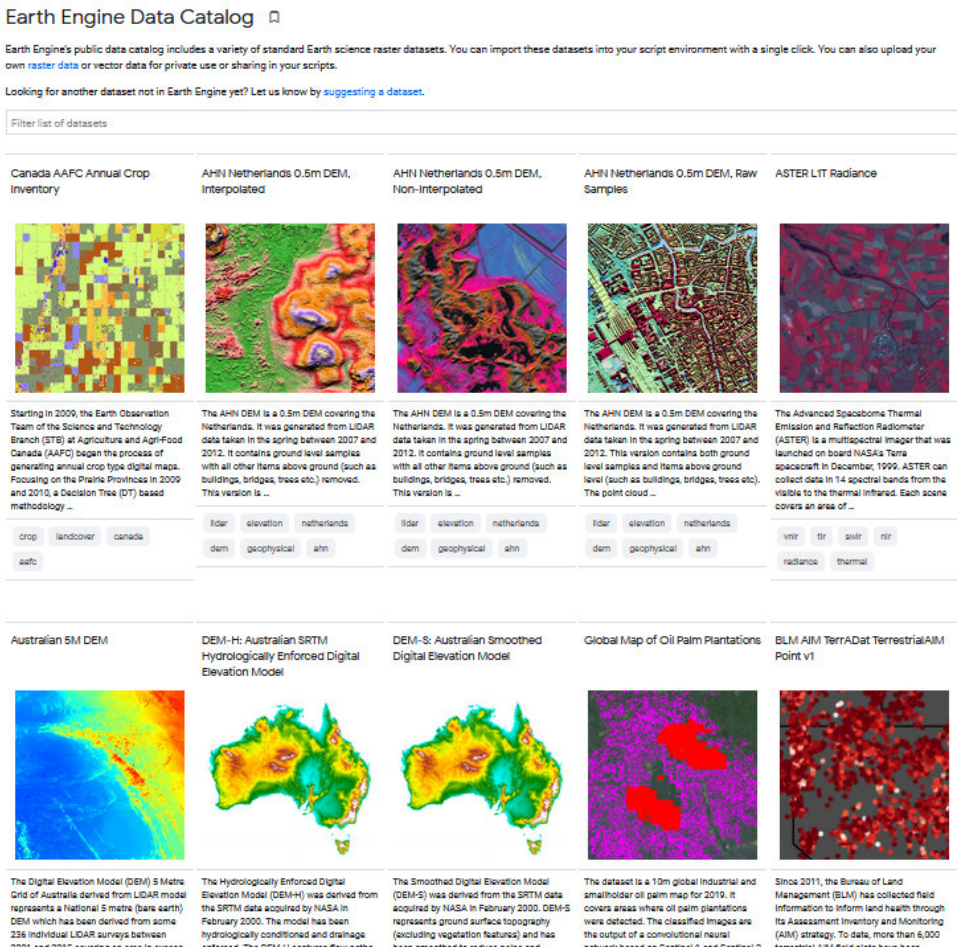
2. Develop open-source tools to construct heat sensitivity, heat adaptive capability indicators and composite heat vulnerability index.

Conceptual and methodological framework



Heat Vulnerability Index (HVI) = Heat Exposure index + Heat Sensitivity index - Adaptive Capability Index .

Cloud-based image analysis



Google Earth Engine combines a multi-petabyte catalog of satellite imagery and geospatial datasets with planetary-scale analysis.

https://developers.google.com/earth-engine/datasets/catalog

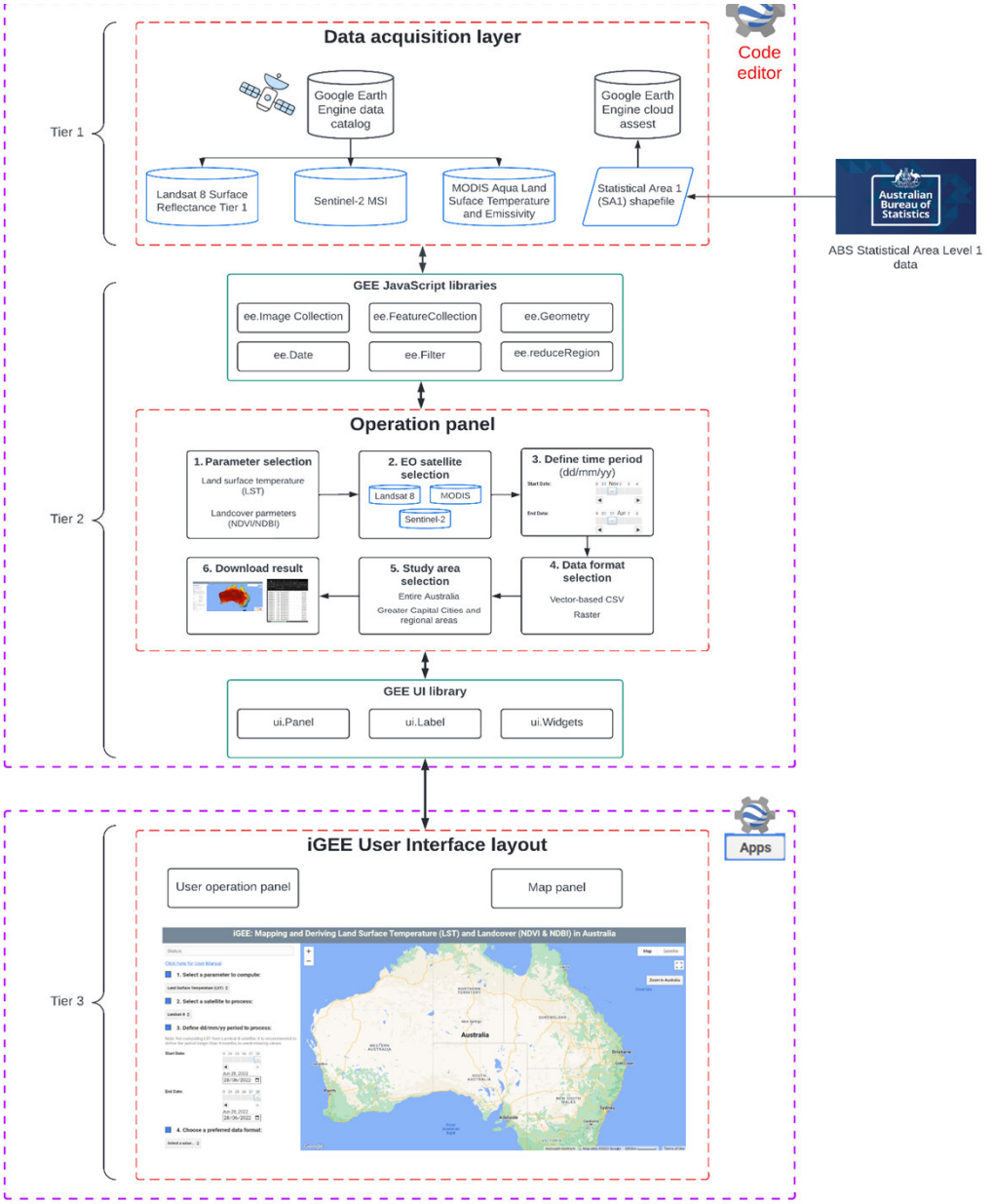
iGEE
(GEE web tool)

System architecture:

Please visit iGEE tool:

www.gisonmeta.com

iHVI toolkit



iGEE System architecture

Data layer (Tier 1)

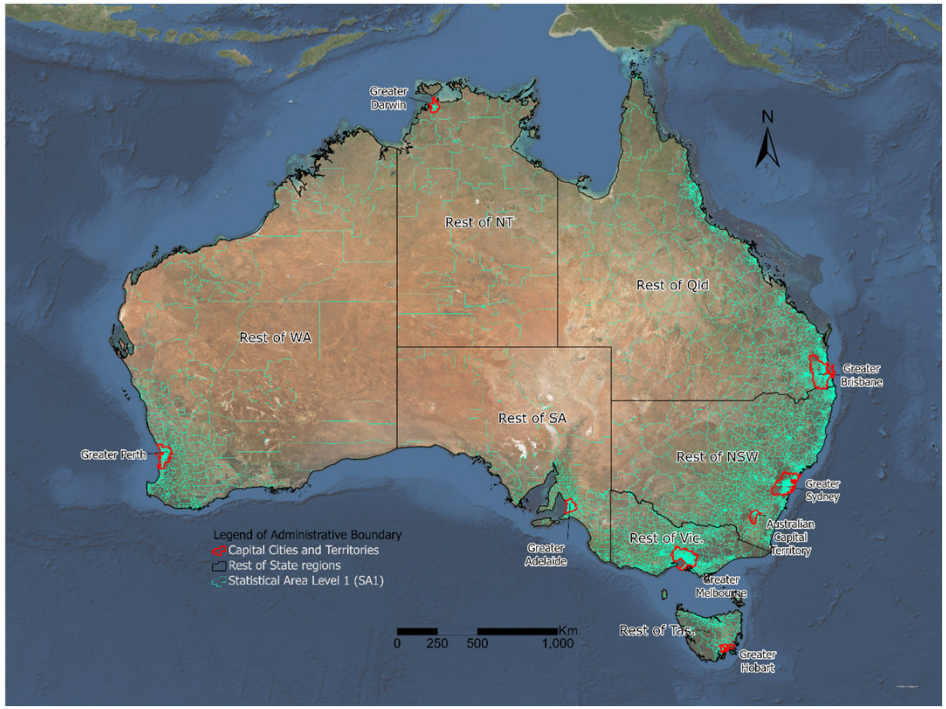
Step 1: Accesses the EO satellites from the GEE data catalog.

Datasets	Spatial resolution (m)	Time period	Spatial Coverage	Satellite image
LST/ UHI - Landsat	30	2013-04-11-present	National scale	USGS Landsat 8 Surface Reflectance Tier 1
LST/UHI-MODIS	1000	2002-07-04-present	National scale	MYD11A2.006 Aqua Land Surface Temperature and Emissivity 8-Day Global 1km
Normalised Difference Built-up Index (NDBI)	10	2015-06-23 - present	National scale	Sentinel-2MSI: Multispectral Instrument, Level-1C
Normalised Difference Vegetation Index (NDVI)	10	2015-06-23 - present	National scale	Sentinel-2MSI: Multispectral Instrument, Level-1C

iGEE System architecture

Data layer (Tier 1)

Step 2: Imports ABS (Australian Bureau of Statistics) fine scale local level Statistical Area Level 1 (SA1s) boundary using GEE ‘Assest Manager’.



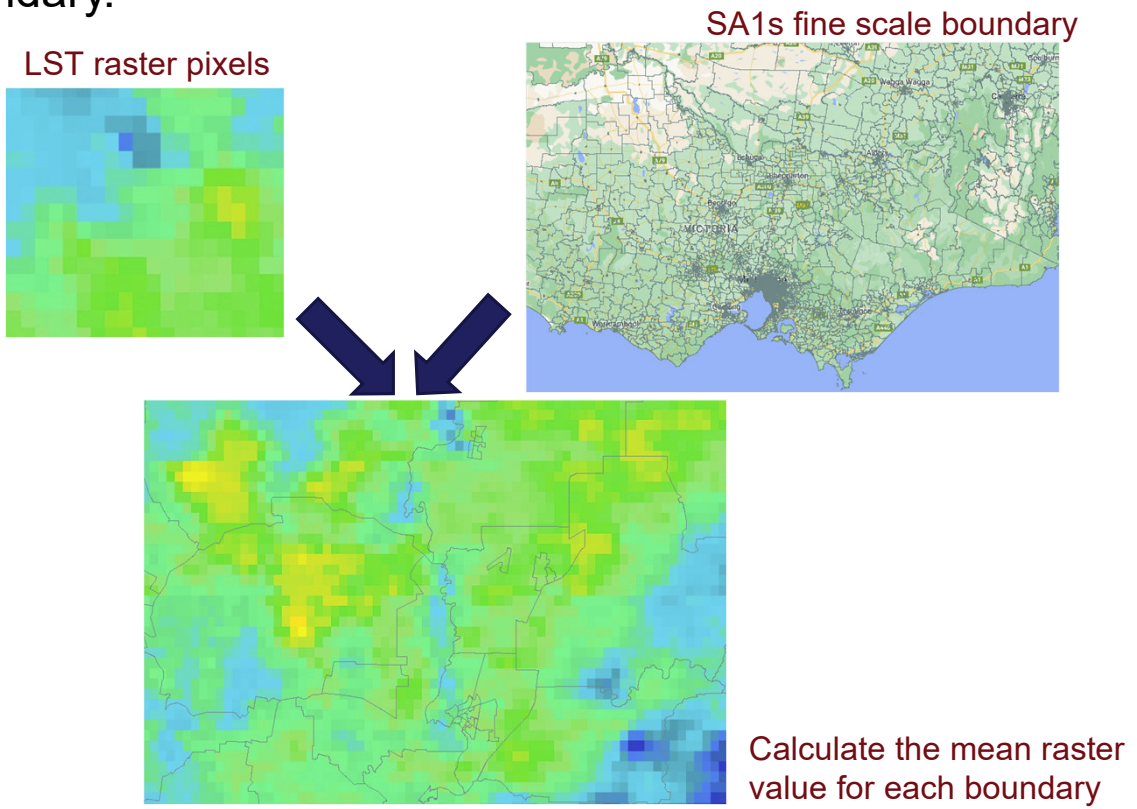
Operational panel (Tier 2)

Step 1: Consists of algorithm to retrieve, analyze and export LST, NDVI and NDBI parameters.

Parameters	Equations derive parameters from GEE	Definition
LST	$NDVI = \frac{NIR - RED}{NIR + RED}$ $FV = \left(\frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}}\right)$ $\varepsilon = 0.004 * FV + 0.986$ $LST = \left(\frac{Band\ 10 * 0.1}{1 + Band\ 10 * 0.1 * 0.00115 + \frac{ln(\varepsilon)}{1+4.88}}\right) - 275.15$	LST is calculated in Celsius (°C) using: $NDVI$ (Normalised Difference Vegetation Index) is calculated using NIR (Band 5) and RED (Band4); FV denotes proportion of vegetation calculated from NDVI; ε indicates land surface emmisivity ; *Band 10* shows at surface brightness temperature.
NDVI	$NDVI = \frac{NIR - RED}{NIR + RED}$	$NDVI$ denotes Normalised Difference Vegetation Index , calculated using the difference between NIR (Band 8) and RED (Band 4).
NDBI	$NDBI = \frac{SWIR - NIR}{SWIR + NIR}$	$NDBI$ denotes Normalised Difference Builtup Index , calculated using the difference between SWIR (Band 11) and NIR (Band 8).

Operational panel (Tier 2)

Step 2: Zonal statistical operations in GEE – vectorization method , attributing mean value of raster pixels to a boundary.



Operational panel (Tier 2)

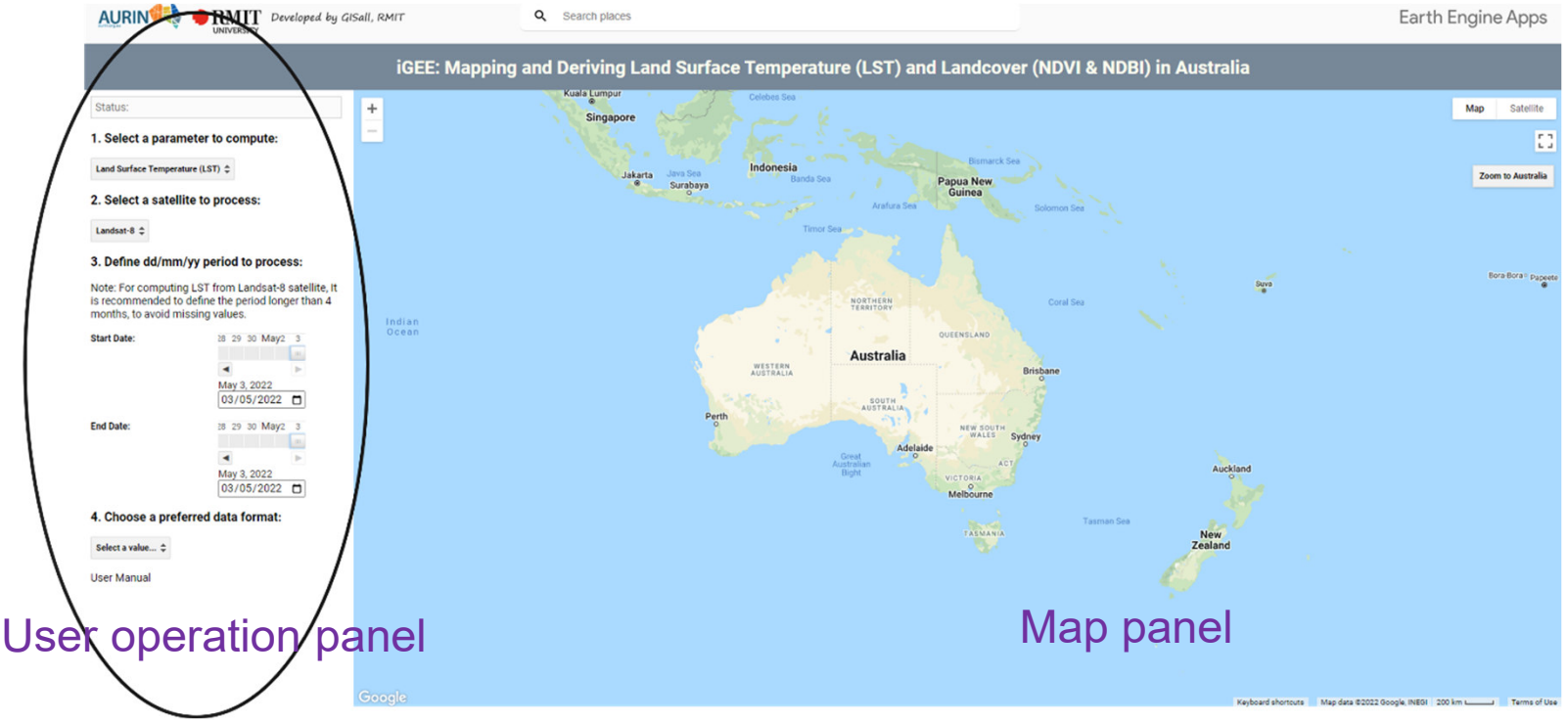
Step 3. Business logic layer – a pipeline to connect and compile JavaScript and GEE UI libraries to build the final iGEE web tool.

GEE ui libraries	Description
ui.Panel.Layout()	A widget that can hold other widgets. This is used to create the panel side user interface.
ui.Panel.Layout.flow()	Returns a layout that places its widgets in a flow, either horizontal or vertical.
ui.Label()	Returns a text label to build the status bar of the web tool
ui.Button()	Creates a clickable button with text label
ui.Select()	This function calls back the results from the operation panel layer
ui.DateSlider()	A draggable target that ranges linearly between two dates. The date slider can be configured to display dates of various interval sizes, including day, 8-day, and year. The value of the slider is displayed as a label alongside it.
ui.Panel.add()	Adds a widget to the panel.

User Interface (Tier 3)

The web tool interface contains a user operation panel and a map panel.

Dynamically executes the retrieval algorithm backend and reloads the on-demand results on the map panel.



User operation panel

Map panel

1. Select a parameter to compute:

Land Surface Temperature (LST)

2. Select a satellite to process:

Landsat 8

3. Define dd/mm/yy period to process:

Note: For computing LST from Landsat 8 satellite, It is recommended to define the period longer than 4 months, to avoid missing values.

Start Date: Oct 18, 2022 18/10/2022

End Date: Oct 18, 2022 18/10/2022

4. Choose a preferred data format:

Vector-based CSV

5. Choose a pre-defined study area for CSV:

Note: For a large study area, iGEE tool will direct to GEE Code Editor for processing.

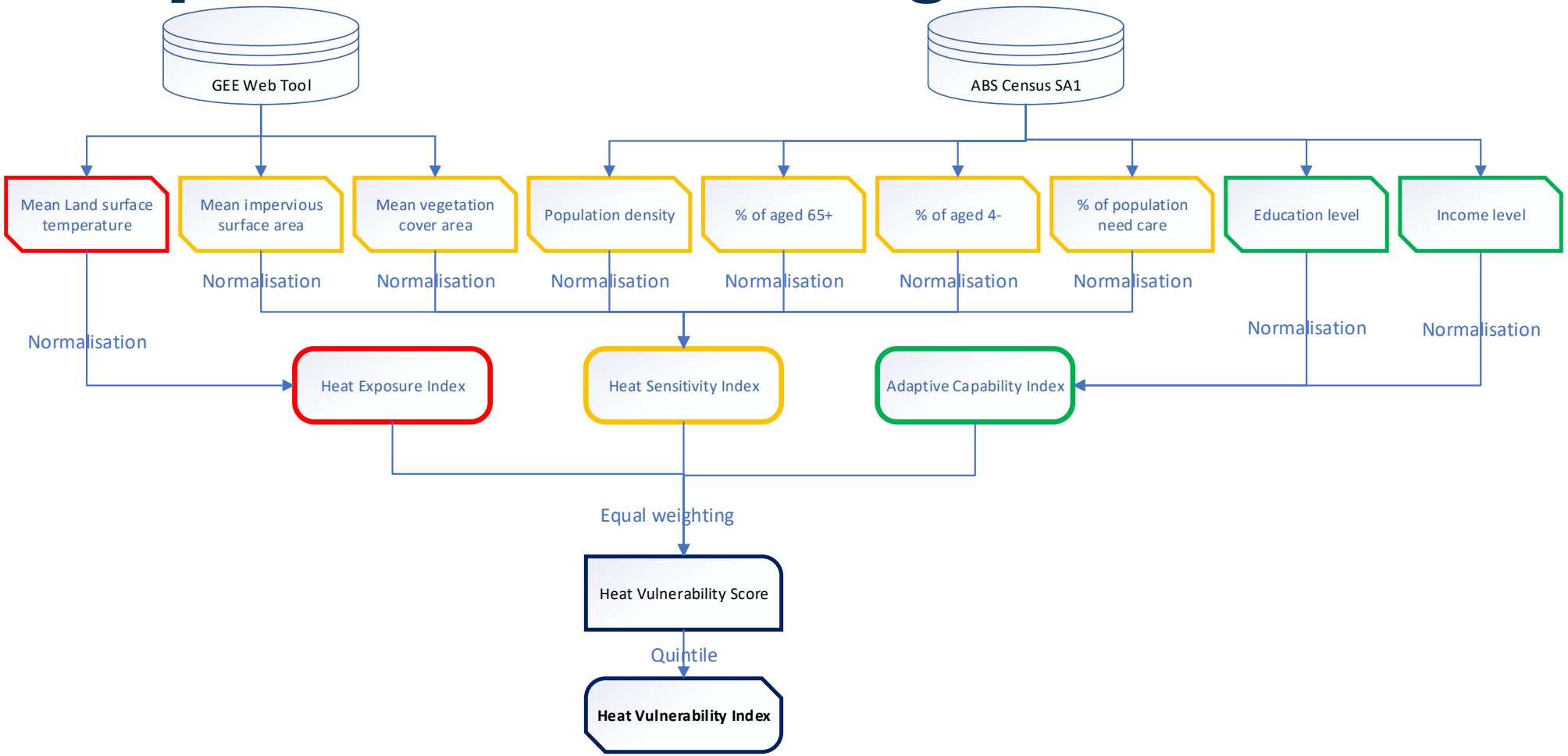
Entire Australia

6. Submit request and download result:

Process request

iGEE link : www.gisonmeta.com

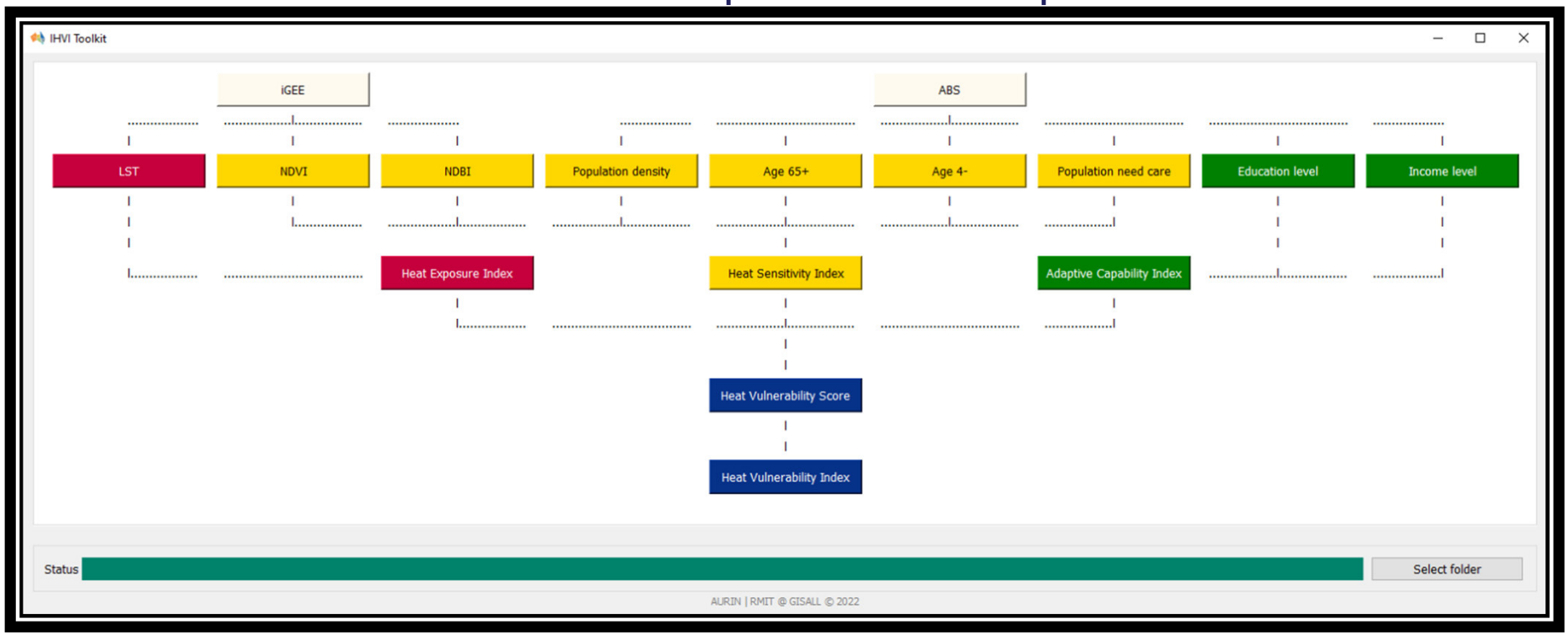
Conceptual and methodological framework



Heat Vulnerability Index (HVI) = Heat Exposure index + Heat Sensitivity index - Adaptive Capability Index .

iHVI Open-source Toolkit

iHVI desktop toolkit development



https://github.com/IGEE-IHVI

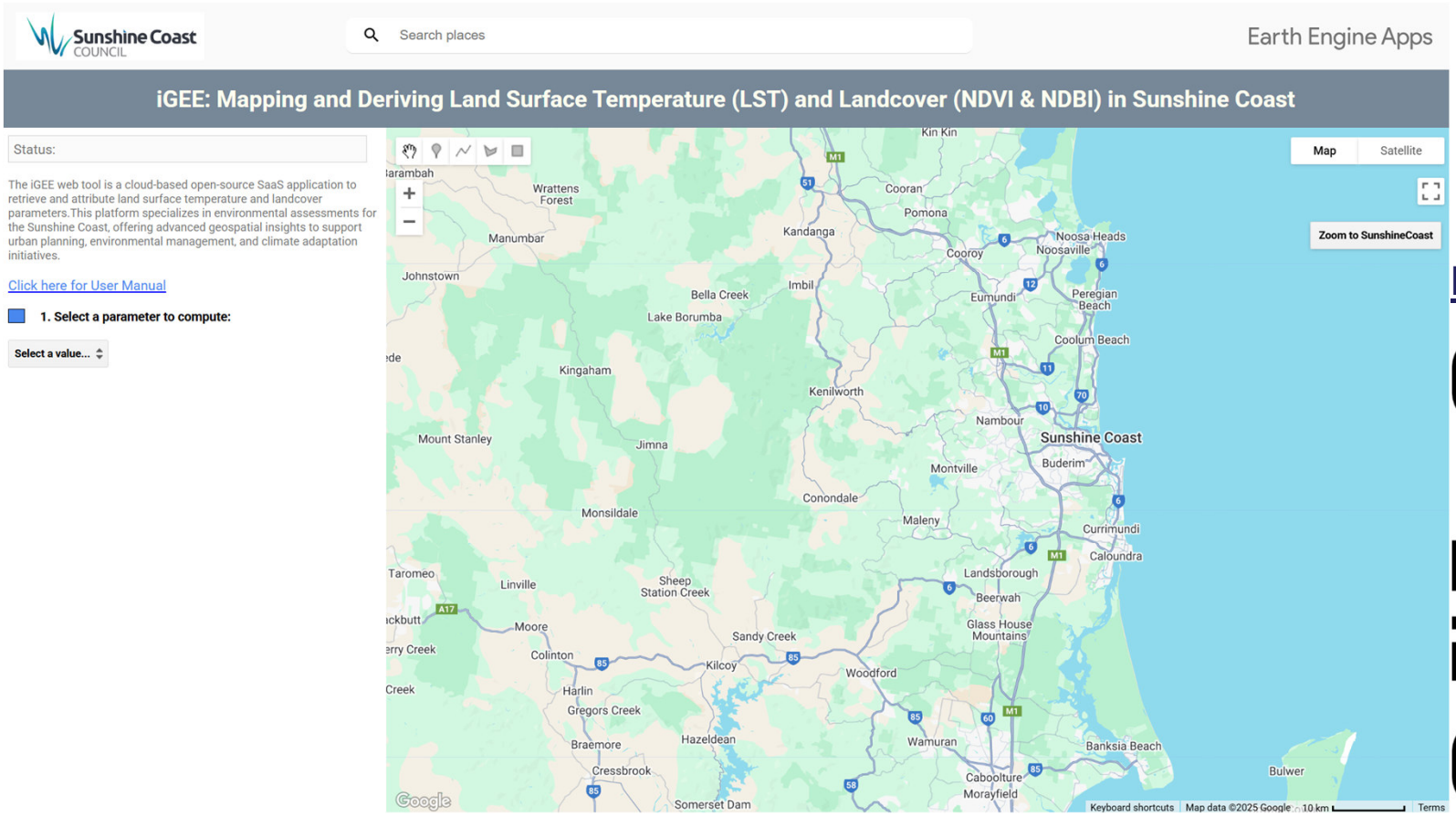
iGEE web tool

- Making the data accessible without computational hassles.
- Enables on-the-fly and dynamic analysis tools to retrieve environmental indicators.
- Researches or developers can just focus on the implementation of the web tool without figuring out the details of GEE APIs.

iHVI desktop tool

- Enable researchers and decision makers to access heat exposure, sensitivity, and adaptive capability indicators for intervention strategies.
- Empower Australians with information and intelligence for better heat mitigation and adaptation.

Sunshine Coast and Noosa iGEE toolkit



Please scan the QR code

HVI project impact

Research at RMIT University in partnership with DELWP and Clear Air and Urban Landscapes Hub (CAUL). The Heat Vulnerability Index (HVI) measures heat exposure, sensitivity to heat and adaptive capability to determine populations that are most vulnerable to heat.

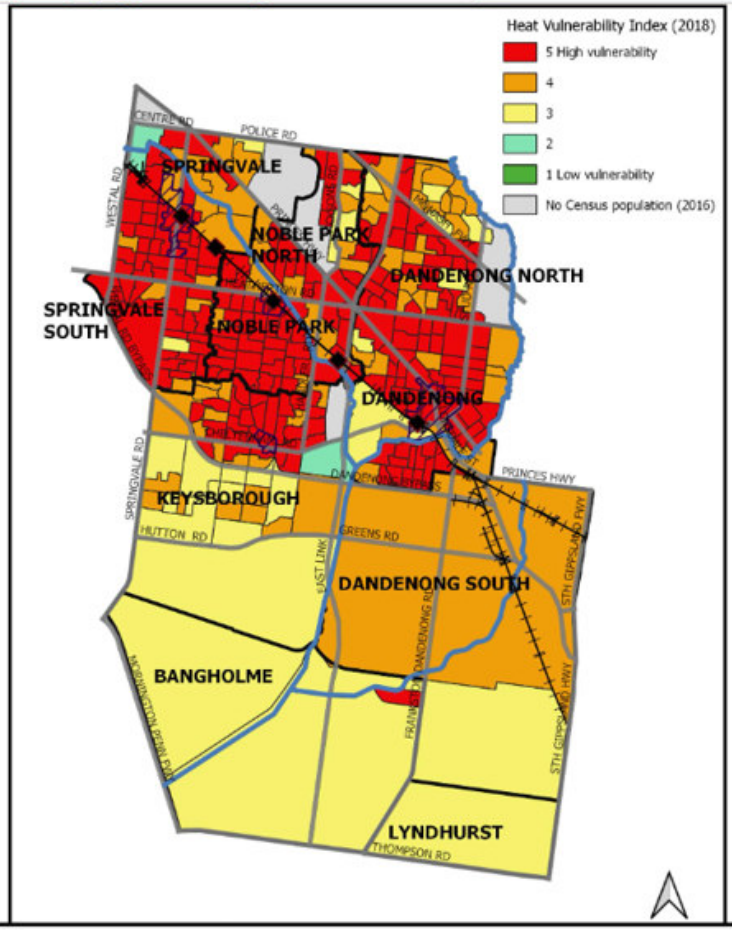
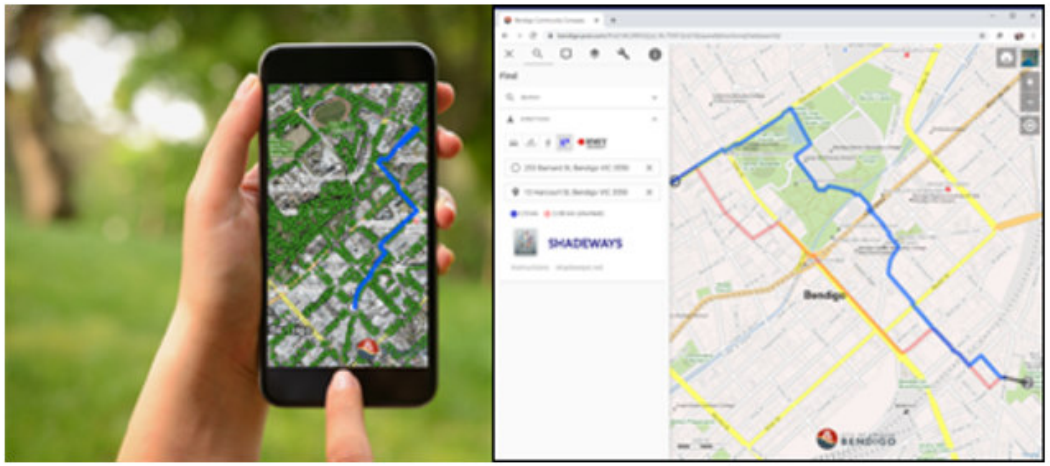


Figure 10 The Heat Vulnerability Index (HVI) identifies which populations are most vulnerable to heat. It consists of three indicators: heat exposure, sensitivity to heat, and adaptive capability. This has been measured at the 2016 Census mesh-block level. Vulnerability ratings range from 1 (low vulnerability) to 5 (high vulnerability). This map demonstrates the City of Greater Dandenong community is highly vulnerable to urban heat due to high heat exposure (lack of shade), sensitivity to heat and low adaptive capability (low socio-economic demographic, people living with disabilities, the elderly and children). The areas denoted light green have low population numbers but are still prone to heat exposure and areas denoted grey had no census population recorded in 2016.

Further information on this can be found in *'Urban Vegetation, Urban Heat Islands and Heat Vulnerability Assessment in Melbourne, 2018'* (Sun, et al., 2019).

GREATER DANDENONG
City of Opportunity



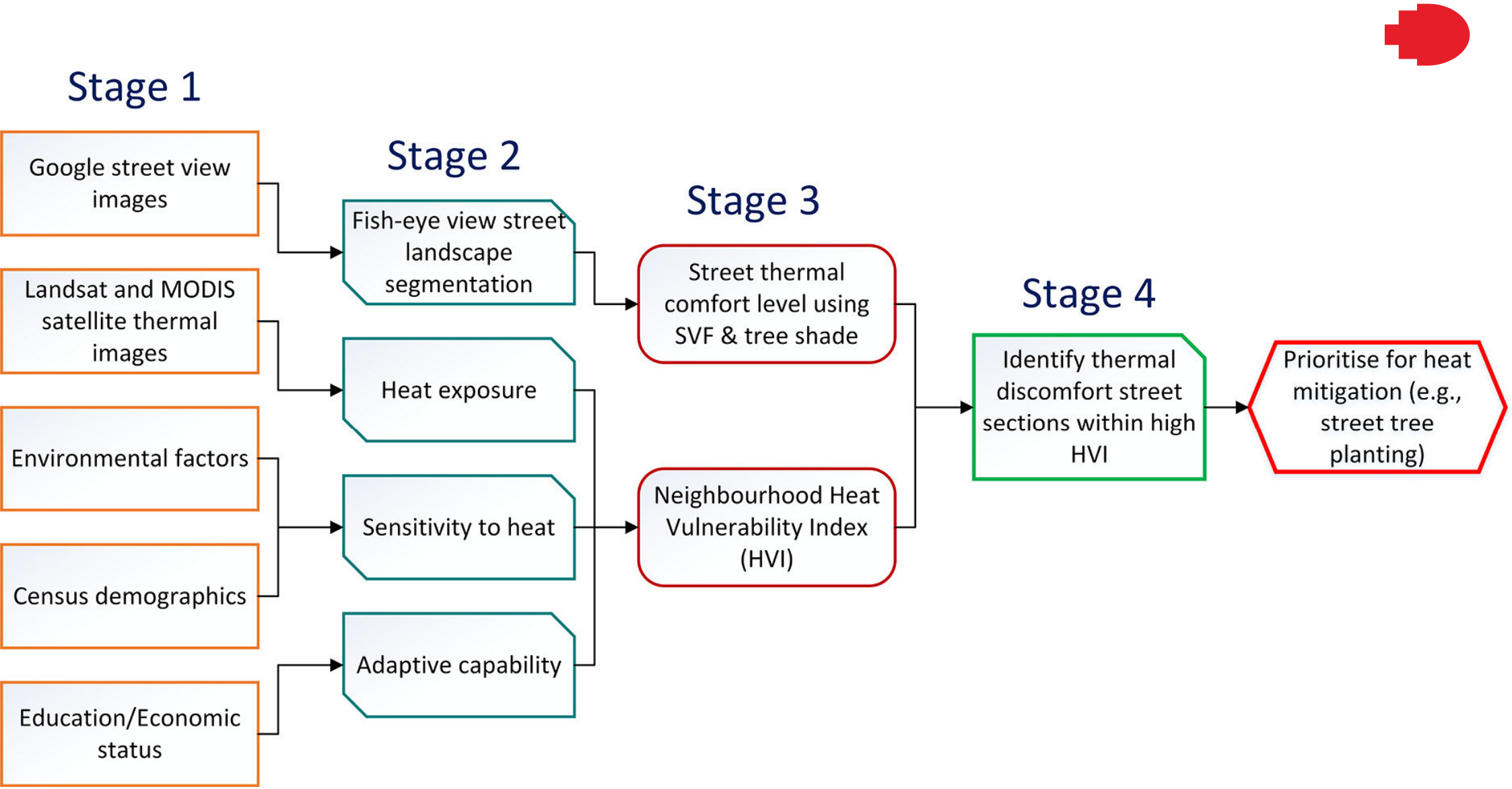
www.shadeways.net

Deilami, Kaveh, et al. "Allowing users to benefit from tree shading: Using a smartphone app to allow adaptive route planning during extreme heat." *Forests* 11.9 (2020): 998.

A human-centred assessment framework to prioritise heat mitigation efforts for active travel at city scale (Sun et al., 2020)

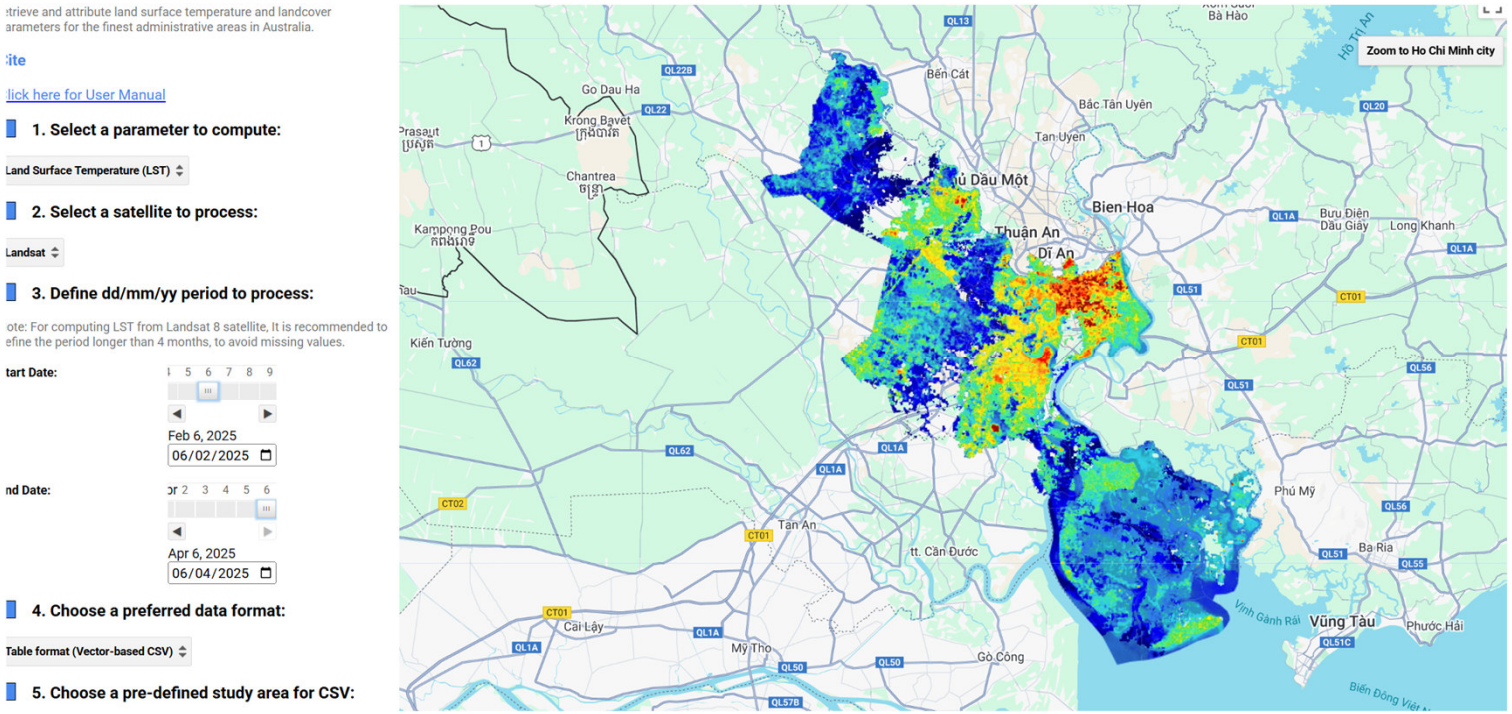
Case study: Bendigo

Sun, Q. C., Macleod, T., Both, A., Hurley, J., Butt, A., & Amati, M. (2020). A human-centred assessment framework to prioritise heat mitigation efforts for active travel at city scale. *Science of The Total Environment*, 143033.


Stage 1
Google street view images
Landsat and MODIS satellite thermal images
Environmental factors
Census demographics
Education/Economic status
Stage 2
Fish-eye view street landscape segmentation
Heat exposure
Sensitivity to heat
Adaptive capability
Stage 3
Street thermal comfort level using SVF & tree shade
Neighbourhood Heat Vulnerability Index (HVI)
Stage 4
Identify thermal discomfort street sections within high HVI
Prioritise for heat mitigation (e.g., street tree planting)

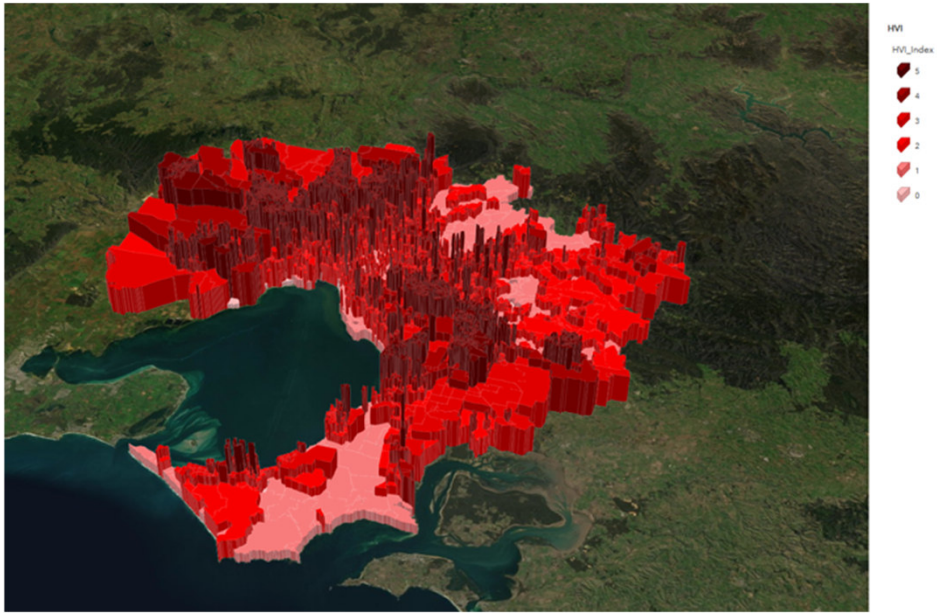
iGEE toolkit for Vietnam

Web-based platform for understanding fine scale spatial patterns of heat, greenery and urbanization in Vietnam



Other data publications

- https://www.planning.vic.gov.au/guides-and-resources/Data-spatial-and-insights/melbournes-vegetation-heat-and-land-use-data
- https://datasets.seed.nsw.gov.au/dataset/nsw-heat-vulnerability-index-to-abs-statistical-area-level-1-2016



References

Das, S., Sun, Q. C., & Zhou, H. (2022). GeoAI to implement an individual tree inventory: Framework and application of heat mitigation. *Urban Forestry & Urban Greening*, *74*, 127634.

Duncan, J., Boruff, B., Saunders, A., Sun, Q., Hurley, J., & Amati, M. (2019). Turning down the heat: An enhanced understanding of the relationship between urban vegetation and surface temperature at the city scale. *Science of the Total Environment*, *656*, 118-128.

IPCC. 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability: Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, ed. M.L. Parry, et al.. Cambridge University Press, Cambridge, UK.

Pörtner, H.-O., Roberts, D. C., Adams, H., Adler, C., Aldunce, P., Ali, E., Begum, R. A., Betts, R., Kerr, R. B., & Biesbroek, R. (2022). Climate change 2022: Impacts, adaptation and vulnerability. *IPCC Sixth Assessment Report*.

Sun, C., Hurley, J., Amati, M., Arundel, J., Saunders, A., Boruff, B., & Caccetta, P. (2019). Urban Vegetation, Urban Heat Islands and Heat Vulnerability Assessment in Melbourne, 2018. *Clean Air and Urban Landscapes Hub, Melbourne, Australia*.

Sun, Q. C., Macleod, T., Both, A., Hurley, J., Butt, A., & Amati, M. (2021). A human-centred assessment framework to prioritise heat mitigation efforts for active travel at city scale. *Science of the Total Environment*, *763*, 143033.


Thank you!
Q + A