Natural Capital Singapore

Project summary

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CREATE Campus for Research Excellence And Technological Enterprise

CUGE Centre for Urban Greenery and Ecology

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Nanyang Technological University Singapore

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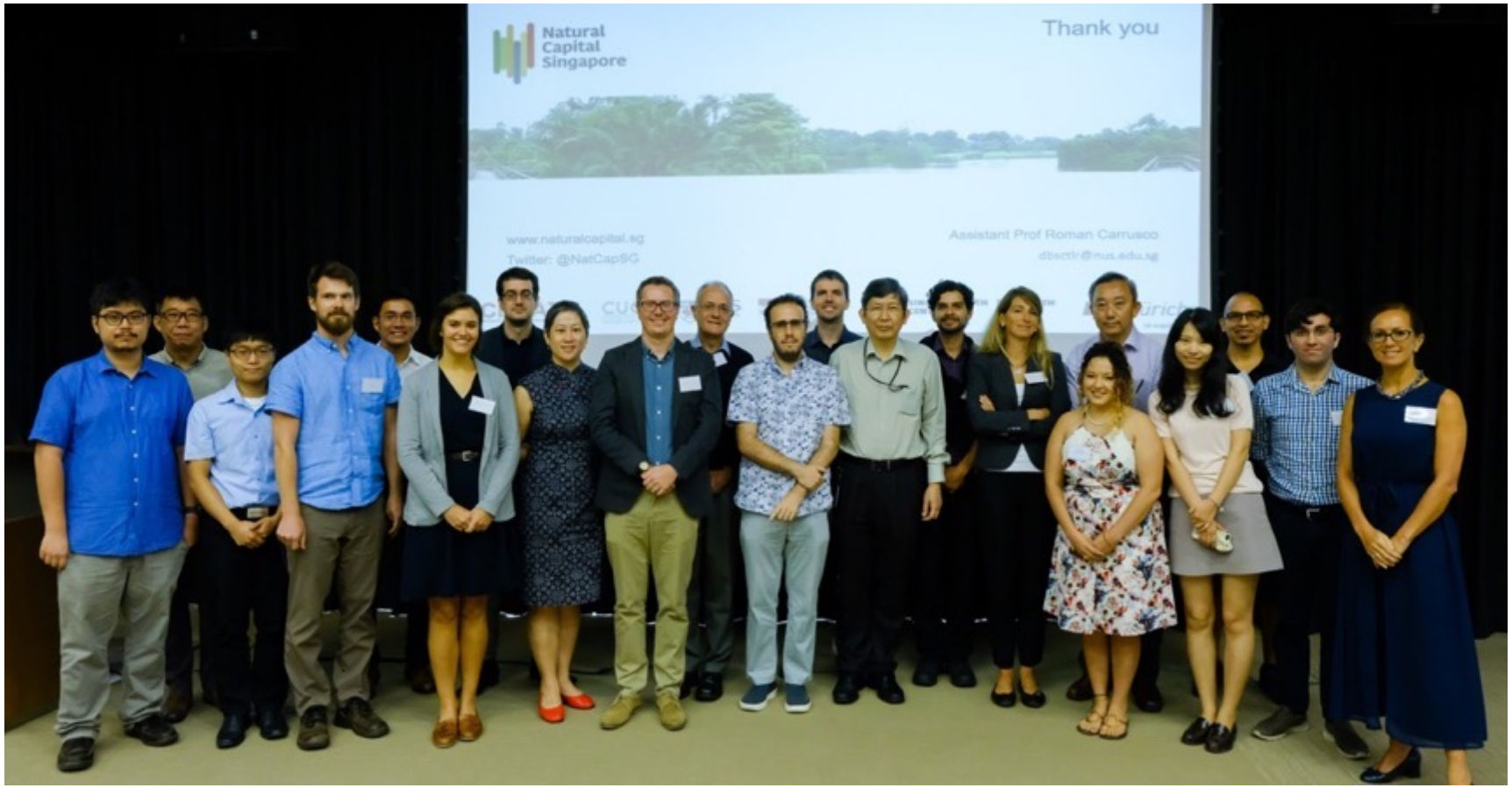
Acknowledgements



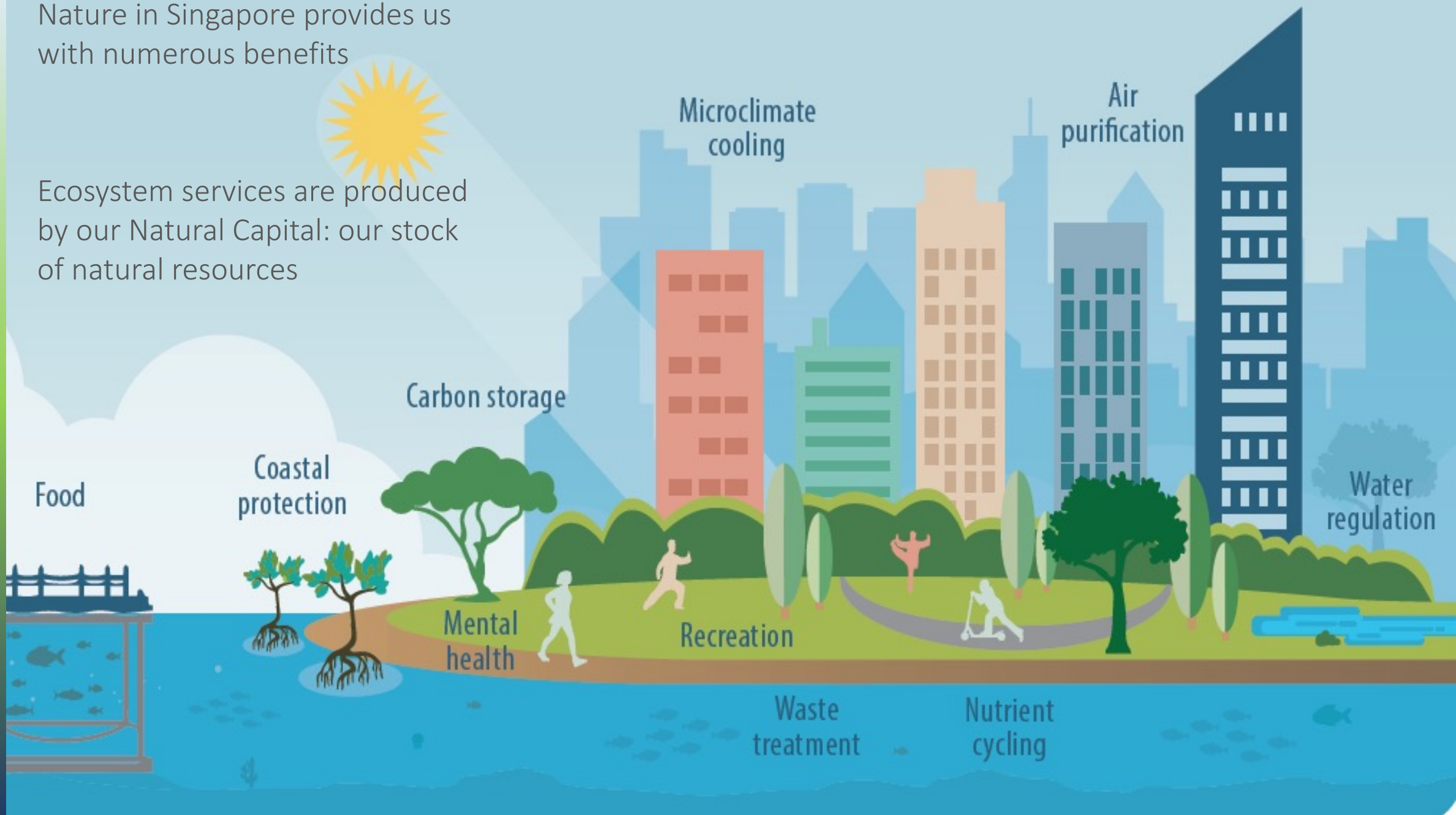
We'd like to thank our:
- 30 staff
- 11 students
- xx interns
- xx govt. collaborators
- 7 PIs
- 8 collaborators
- 4 IAP

CREATE
Campus for Research Excellence And Technological Enterprise

National Research Foundation
Prime Minister's Office
Singapore

Nature in Singapore provides us with numerous benefits

Ecosystem services are produced by our Natural Capital: our stock of natural resources



Assessing Singapore's Natural Capital

Aim: To quantify the economic, social and cultural value of Singapore's environmental assets to aid future policy and urban development

Jan 2018

Jun 2021

THIS MORNING (SGT)

- **Objective 1:** quantify the *current status* of Singapore's terrestrial and coastal-marine ecosystems
- **Objective 2:** *quantify* and *value* Singapore's ecosystem services to society – both economic and societal

THIS AFTERNOON (SGT)

- **Objective 3:** assess *interactions* between urban development (urban assets) and natural capital (natural assets)
- **Objective 4:** assess *future policy and development opportunities* that integrate natural capital within a sustainable future city

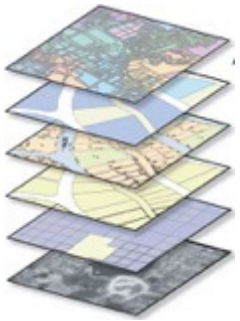
Objective 1

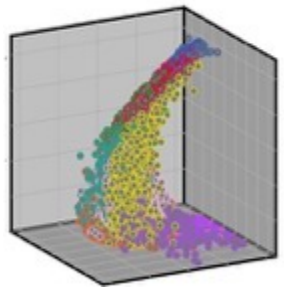
Quantify the current status of Singapore's ecosystems

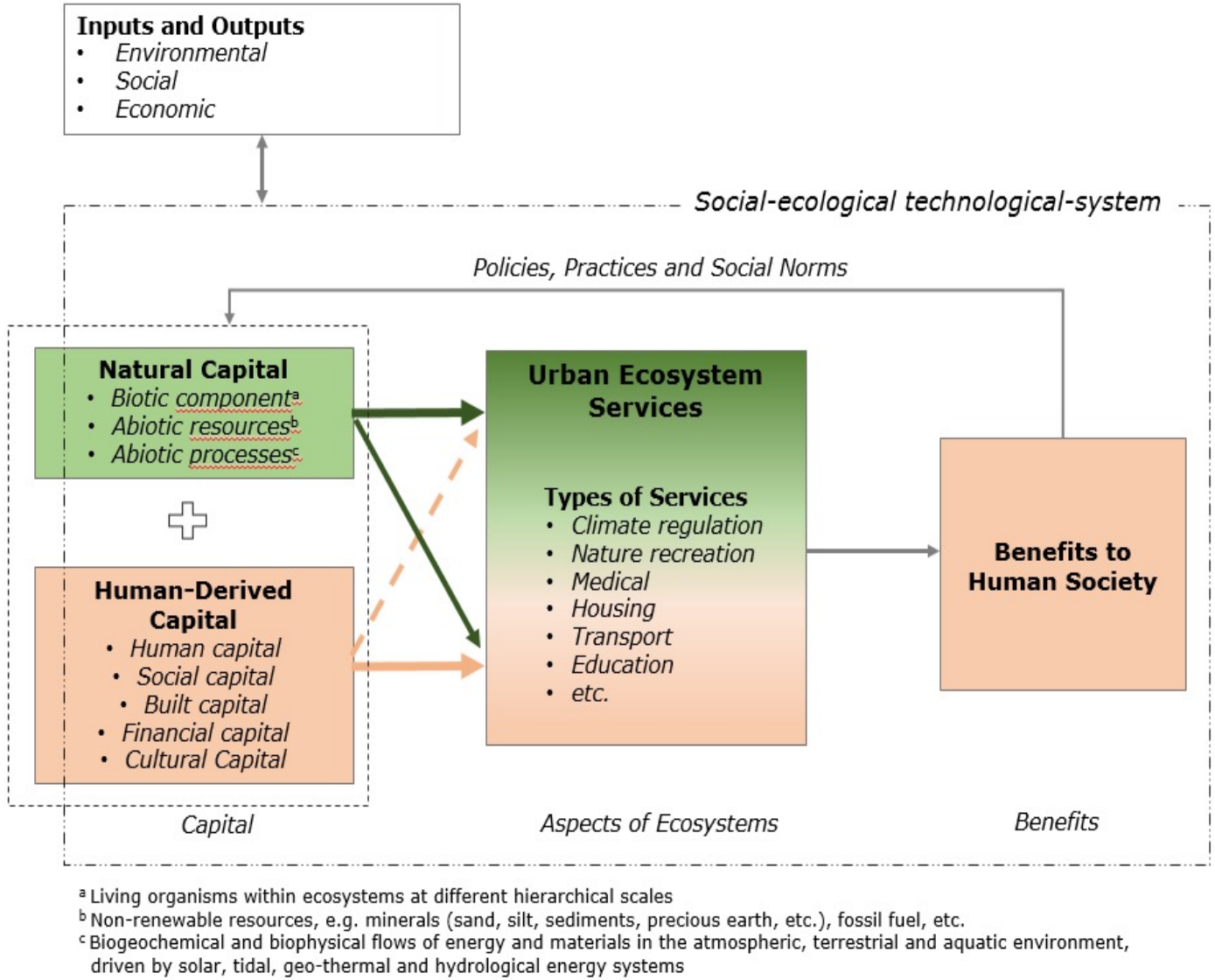
What is an ecosystem?

First we need to define what an ecosystem is!

Components	Materials	Configuration	Time/Dynamics
Aspects	A1: Human constructions A2: Soil-Plant continuum A3: Surface waters	A4: Dimensionality A5: Spatial pattern	A6: Time

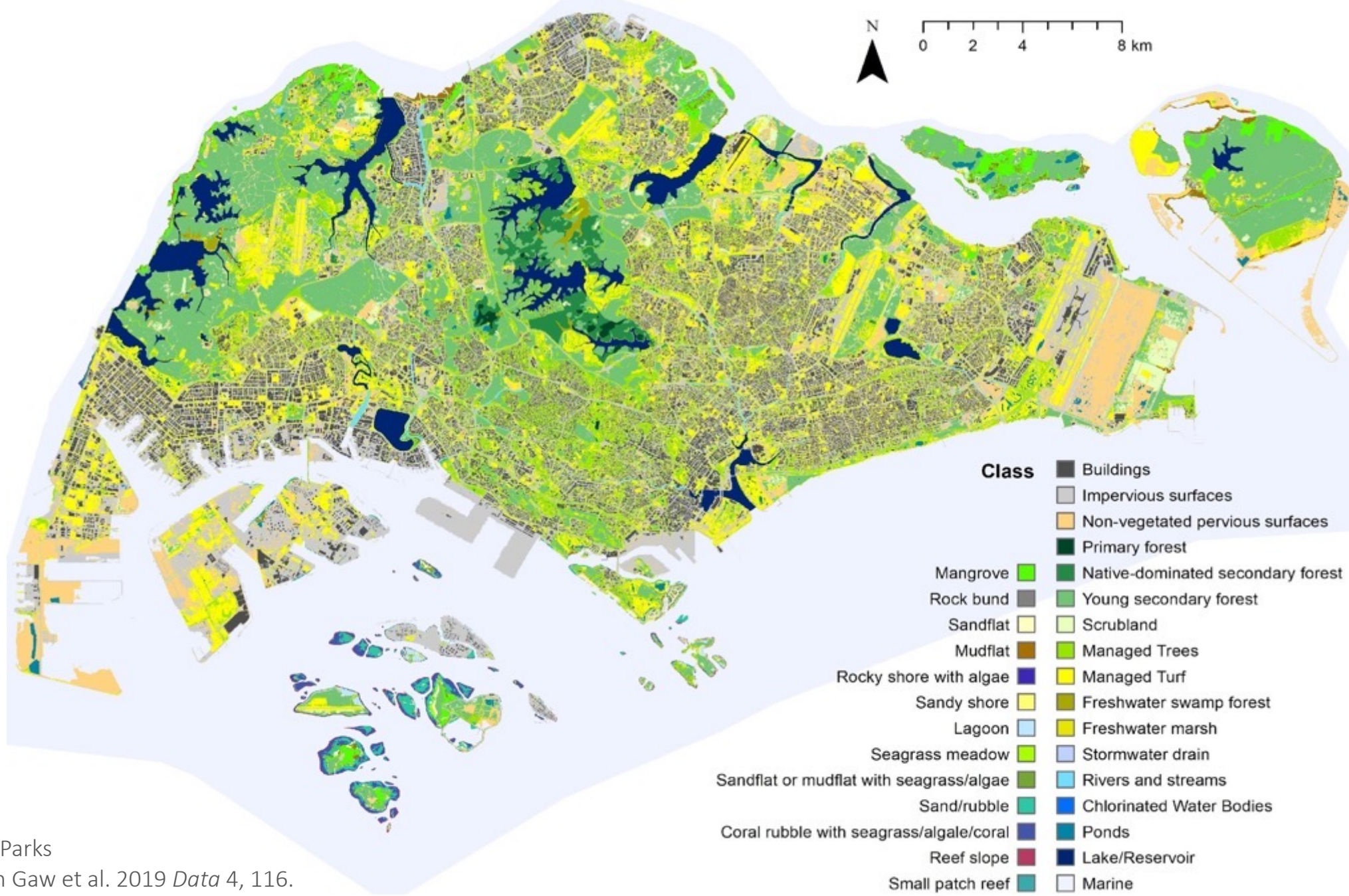




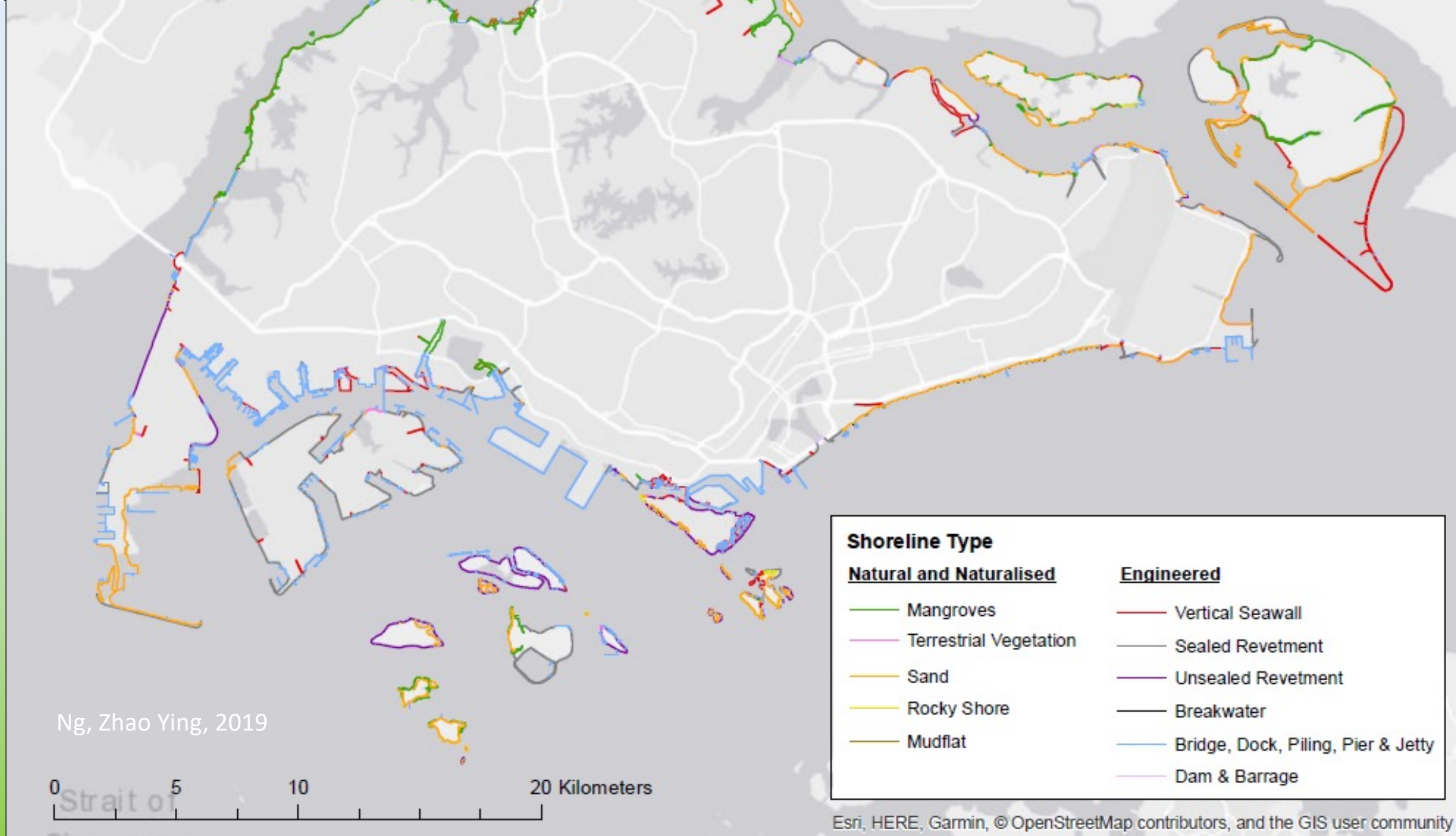


[a] Living organisms within ecosystems at different hierarchical scales
[b] Non-renewable resources, e.g. minerals (sand, silt, sediments, precious earth, etc.), fossil fuel, etc.
[c] Biogeochemical and biophysical flows of energy and materials in the atmospheric, terrestrial and aquatic environment, driven by solar, tidal, geo-thermal and hydrological energy systems

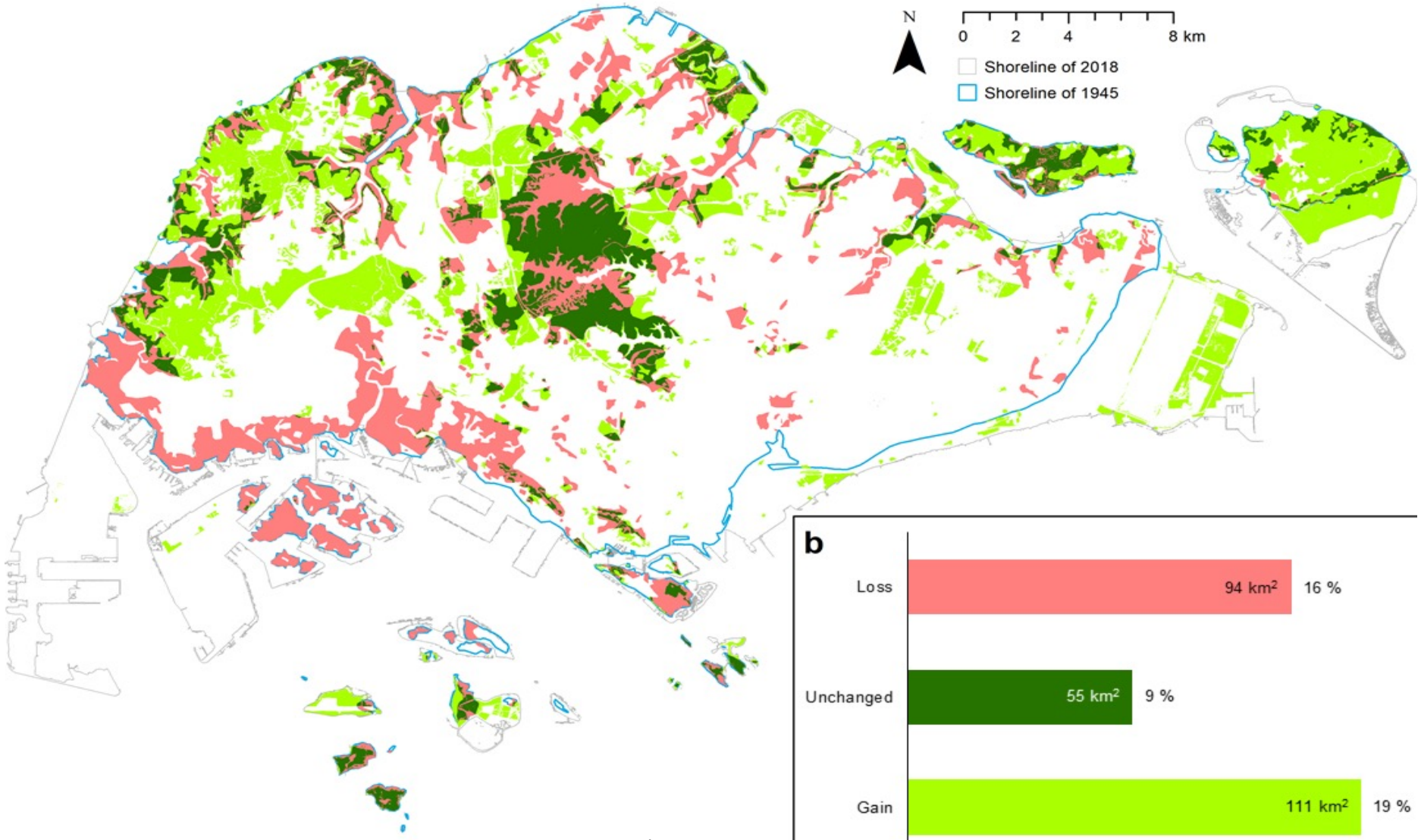
Tan et al. 2020. *Landscape and Urban Planning* 200, 2-11.



Marine data from NParks
Terrestrial data from Gaw et al. 2019 *Data* 4, 116.


Shoreline Type
Natural and Naturalised
Mangroves
Terrestrial Vegetation
Sand
Rocky Shore
Mudflat
Engineered
Vertical Seawall
Sealed Revetment
Unsealed Revetment
Breakwater
Bridge, Dock, Piling, Pier & Jetty
Dam & Barrage
Ng, Zhao Ying, 2019
0
5
10
20 Kilometers
Strait of
Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community

Historical change



Gaw et al. *in review*

Objective 2a

Quantify Singapore's ecosystem services

Status

Complete

In progress

Likely but not measured

		Regulating								Cultural							Provisioning			
		Global Climate Regulation	Temperature reduction	Coastal Protection	Runoff retention	Water quality regulation	Air pollution mitigation	Noise abatement	Soil erosion reduction	Recreation	Health and well-being	Cultural heritage	Artistic inspiration	Scientific Value	Education	Existence value	Food provision	Water supply	Transportation (ie shipping)	Energy Provision
Terrestrial & Freshwater	Forest	■	■		■	■	■	■	■	■	■	■	■	■	■	■				
	Managed vegetation	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■			
	Vegetated buildings	■	■		■	■	■	■		■	■	■	■	■	■	■				
	Shrub, scrub & turf	■	■		■	■	■		■	■	■	■	■	■	■	■				
	Swamp forest and marsh	■	■		■	■	■	■	■	■	■	■	■	■	■	■				
	Reservoirs and lakes				■	■				■	■	■	■	■	■	■	■	■		
	Rivers and streams				■	■				■	■	■	■	■	■	■	■			
Coastal & Marine	Mangrove	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■			
	Seagrass	■		■	■	■			■	■	■	■	■	■	■	■	■			
	Tidal flat	■		■		■				■	■	■	■	■	■	■	■			
	Coral reef			■		■				■	■	■	■	■	■	■	■			
	Beach									■	■	■	■	■	■	■				
	Open water									■	■	■	■	■	■	■	■	■	■	■
	Artificial substrates			■						■	■	■	■	■	■	■				

Overview of the terrestrial work stream

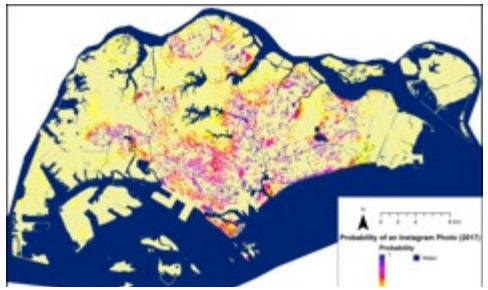
Conceptual research

- Overcoming the conceptual ambiguities surrounding the concept of urban ecosystem services
- Factors behind prioritization of urban ecosystem services
- The potential of vegetation to mitigate air pollution – a global perspective

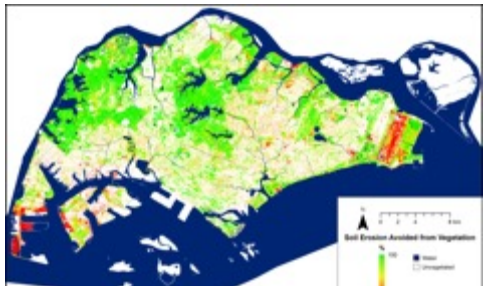
Field and modelling research

- A high resolution map of Singapore's terrestrial ecosystems
- Mapping national-scale leaf area index using Google Street Views and remote sensing satellite imagery
- Mapping the supply of urban ecosystem services
- Historical change in provision and use ecosystem services
- Assessment of distribution of selected ecosystem services from environmental justice and spatial equity perspective
- Typology for urban landscape – Getting urban ecosystem services into urban planning and design
- Impact assessment of the newly proposed Master Plan using Tengah as a case study
- Assessment of modifiable area unit problem in spatial pattern analysis of Singapore's landscape
- Importance of the choice of reference temperature in mapping urban heat island effect
- Study of the effect of thermal resolution of land cover map on cooling effect of vegetation
- Changes in natural vegetation during a period of rapid urbanization in Singapore
- Contribution of reclaimed lands to spontaneous vegetation

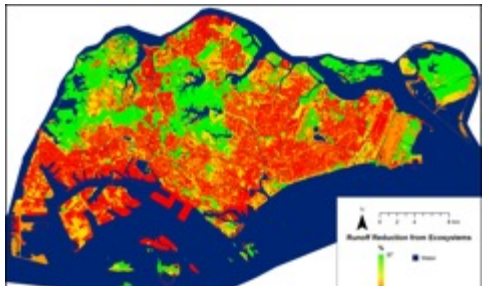
Modelling terrestrial ecosystem services



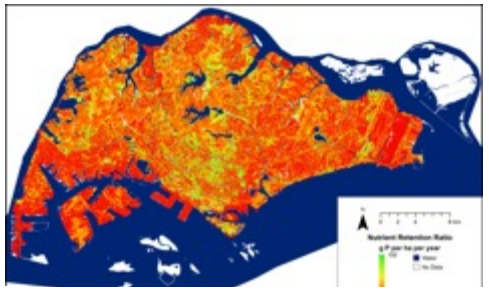
Recreation potential



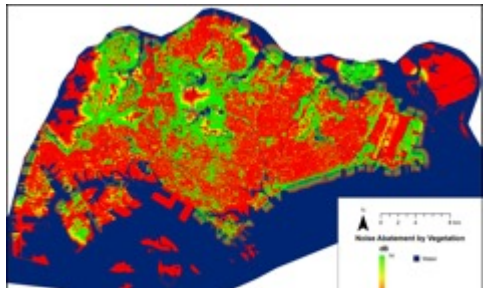
Soil erosion control



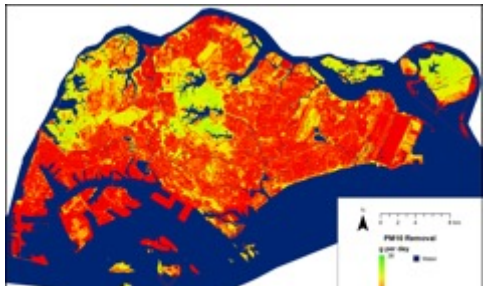
Flood risk reduction



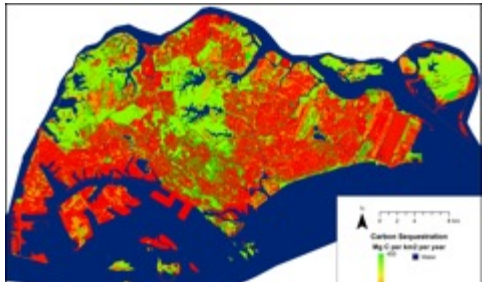
Nutrient regulation (phosphorous)



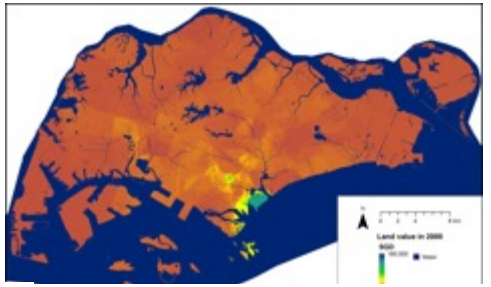
Noise abatement



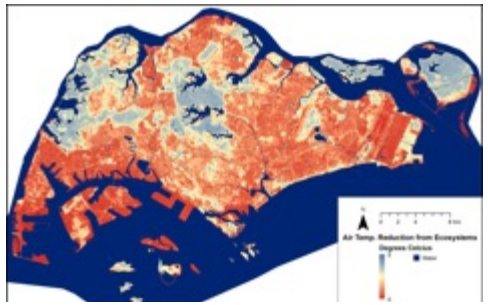
Air quality regulation



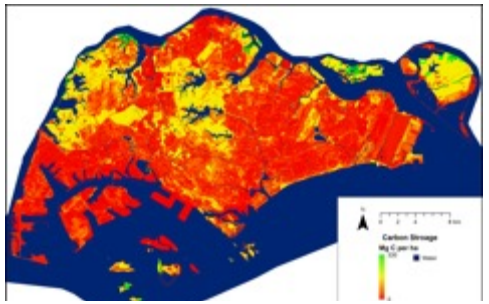
Carbon sequestration



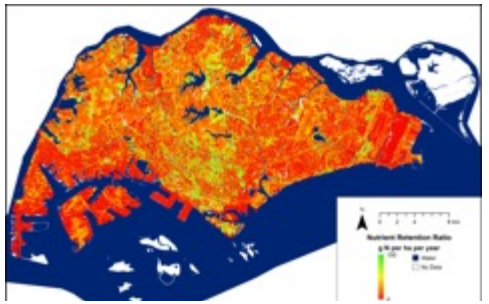
Land value



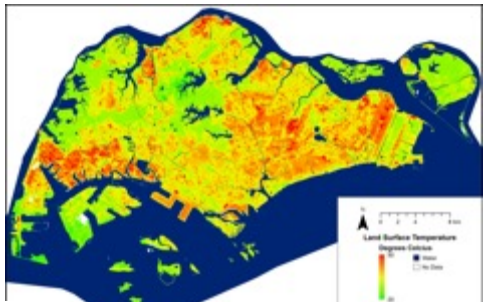
Microclimate regulation



Carbon storage



Nutrient regulation (nitrogen)

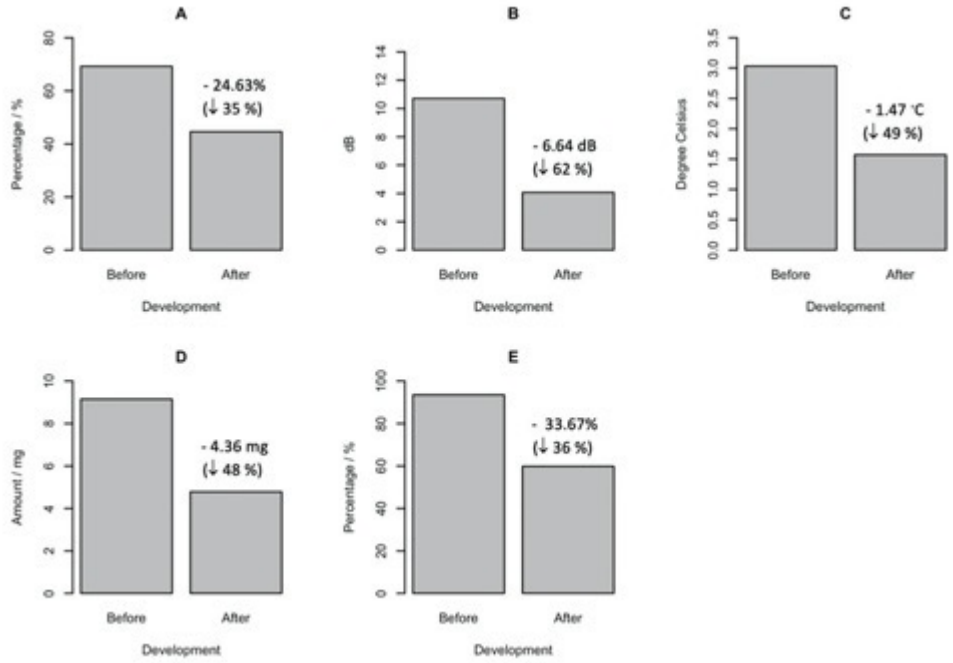


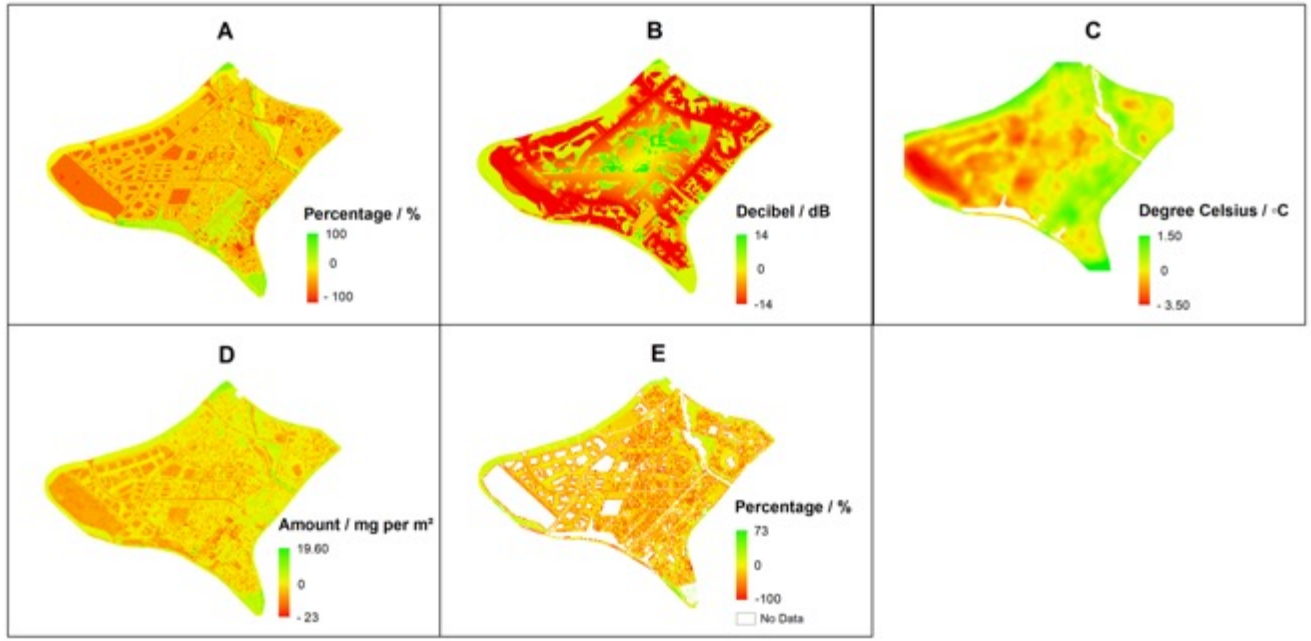
Land surface temperature

R code available here: https://doi.org/10.6084/m9.figshare.13339055.v1

Potential for sub-national analyses

Only for datasets and models that
are designed at this scale





Tan et al. *in press. Frontiers in Environmental Science*

Key terrestrial take aways

- A typology for urban landscape integrating social and ecological components has been developed to inform urban development practice
- Provides a benchmark of the status of natural capital and the ecosystem services they provide
- Over time, there has been a shift from provisioning to regulating ecosystem services in Singapore and similar shifts may happen in the future

Overview of the coastal and marine work package

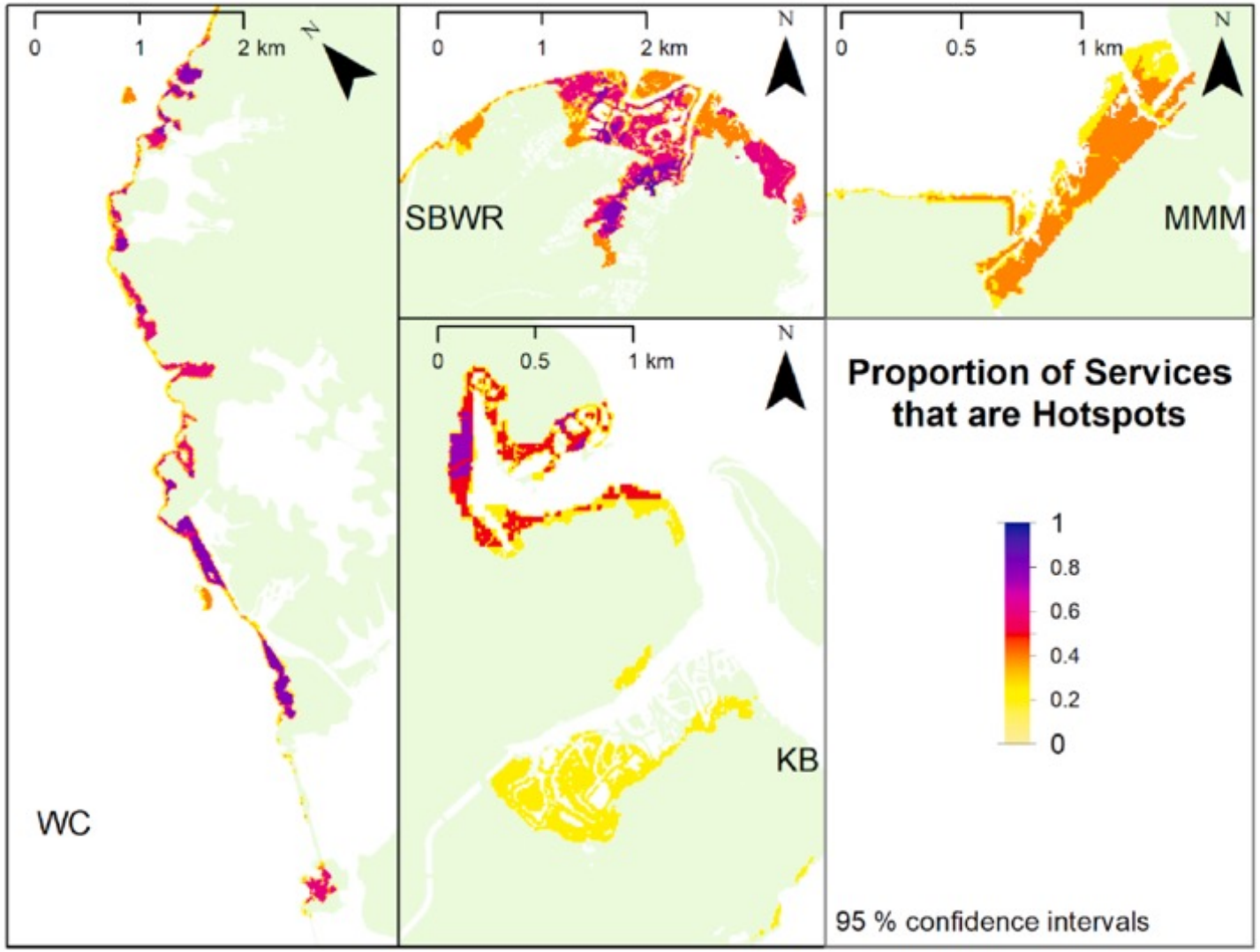
Conceptual research

- Global review of tropical coastal ecosystem services
- Global review of ecosystem services and disservices of mangrove forests and saltmarshes
- Creating Indicators for under-research ecosystem services e.g., scientific value

Field and modelling research

- Blue carbon stocks and sequestration within mangroves, seagrasses and tidal flats
- Blue carbon dynamics across coastal boundaries and ecotones
- Coastal protection of mangrove forests in Singapore
- Open water ecosystem services (anchorages, aquaculture)
- Identifying spatial patterns and interactions among multiple ecosystem services in mangroves
- Scientific value of Singapore’s coastal and marine ecosystems
- Rapid assessment and characterization of recreational fishing in Singapore
- Assessing the recreational value of Singapore’s coral reefs

Hotspots of mangrove ecosystem services

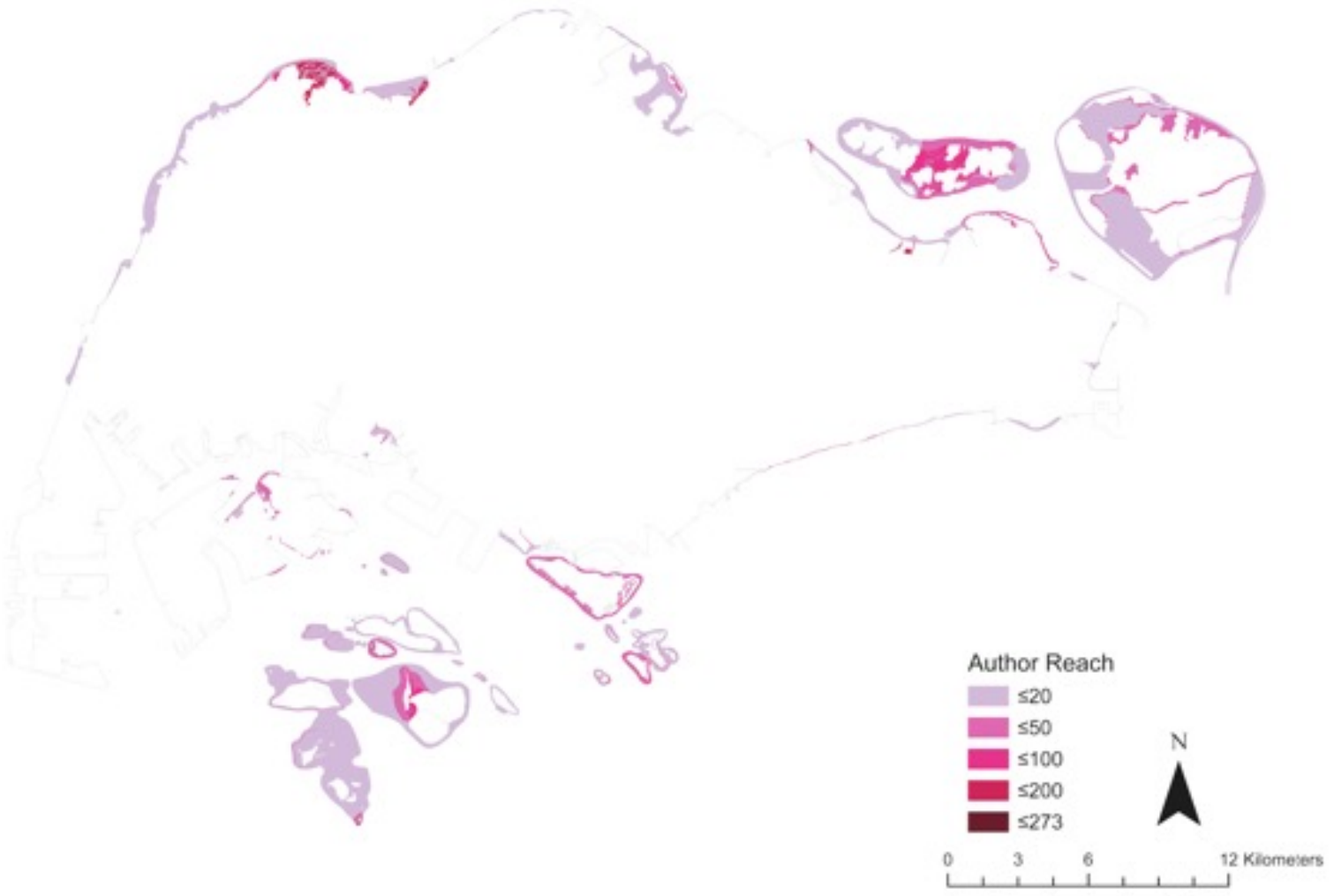


Which mangroves provide the best combination of:

- Nutrient regulation
- Air quality regulation
- Temperature regulation
- Global climate regulation (carbon)
- Recreation

Alemu et al. 2021. *Ecological Indicators* 121, 107042.

Scientific value



11 novel indicators across 3 tiers, allowing flexibility according to data availability

Table 3
Ecosystem-level indicators of scientific value (Tier 1), ranked by total score across all indicators. For method of calculation see Section 3.3.

Ecosystem	Indicator					
	1.1 # of articles	1.2 Ecosystem Impact Factor	1.3 # new species	1.3 # new genera	1.4 Author reach	Overall ranking/ 10
Mangrove	173	25.54	67	4	485	1.4
Reef	162	22.44	10	1	574	2.8
Open water	158	26.46	7	0	472	3.2
Beach	76	22.16	12	2	189	4
Tidal flat	80	16.14	14	0	198	4.6
Rocky shore	40	23.08	6	0	93	5.6
Seawall	42	16.50	0	0	145	6.6
Other	33	20.88	0	0	80	7.2
Seagrass	30	11.67	3	0	103	7.6
Unknown	11	20.36	4	0	24	7.6

Friess et al. 2020. *Ecological Indicators* 113, 106255.

Scientific value

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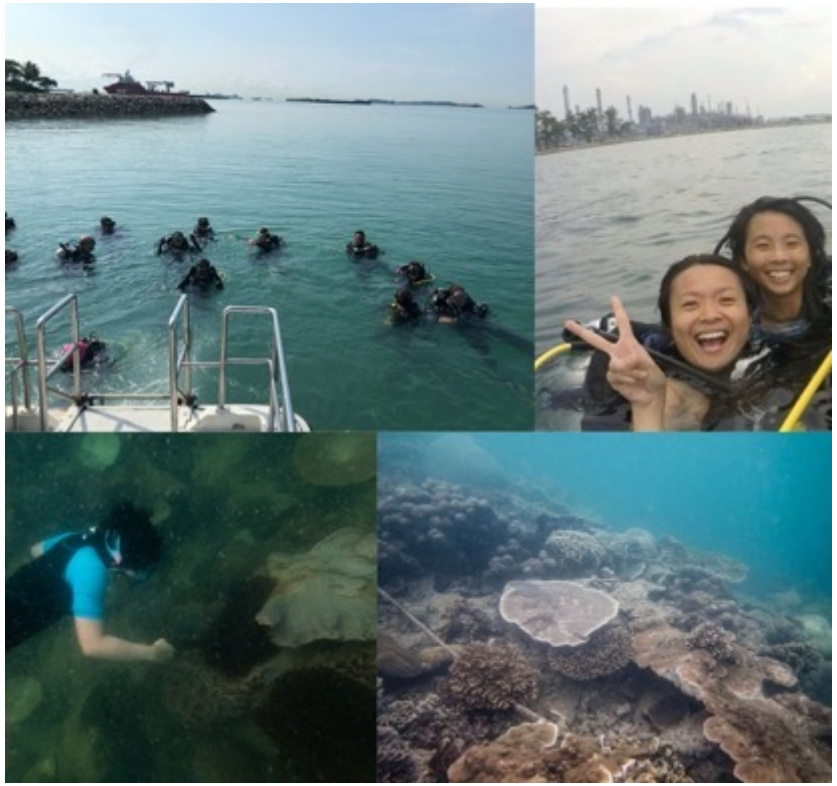
Recreational use of coastal and marine habitats

Density of recreational fishing (Lynn Wong)



Survey of recreational diving in Singapore (Gwen Chow)

Key coastal & marine take aways

- Singapore's coastal and marine ecosystems provide a range of ecosystem services, despite their small and fragmented extent
- Spatial patterning has an important control on ecosystem service hotspots
- Some ecosystems (e.g., mangroves) and some ecosystem services (e.g., global climate regulation/carbon) are more intensively studied than others
- Knowledge of coastal and marine ecosystem services lags behind terrestrial knowledge, and warrants future research

Objective 2b

Quantify the economic and societal value Singapore's ecosystem services

Overview of the valuation work stream

Economic valuation

- Discrete choice experiments
- Market valuation
- Mobile phone data and travel cost valuation
- Park supply

Social valuation

- Ecosystem service ranking by the Public
- Participatory mapping
- Q methodology

Equity in valuation

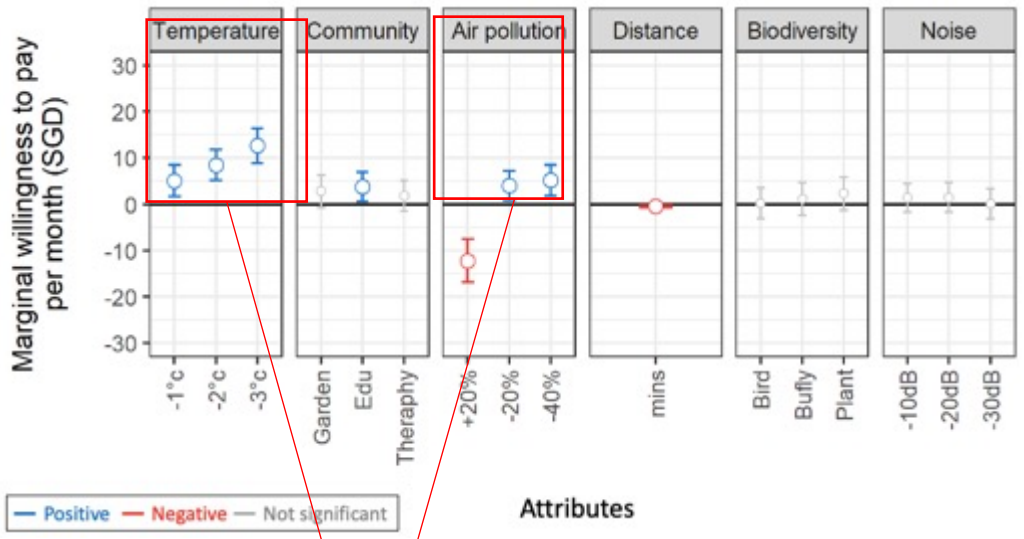
- Demand-supply matching/mismatching
- Spatial equity

Other studies

- How ecosystem service values have changed with COVID-19
- Health value
- Relational values

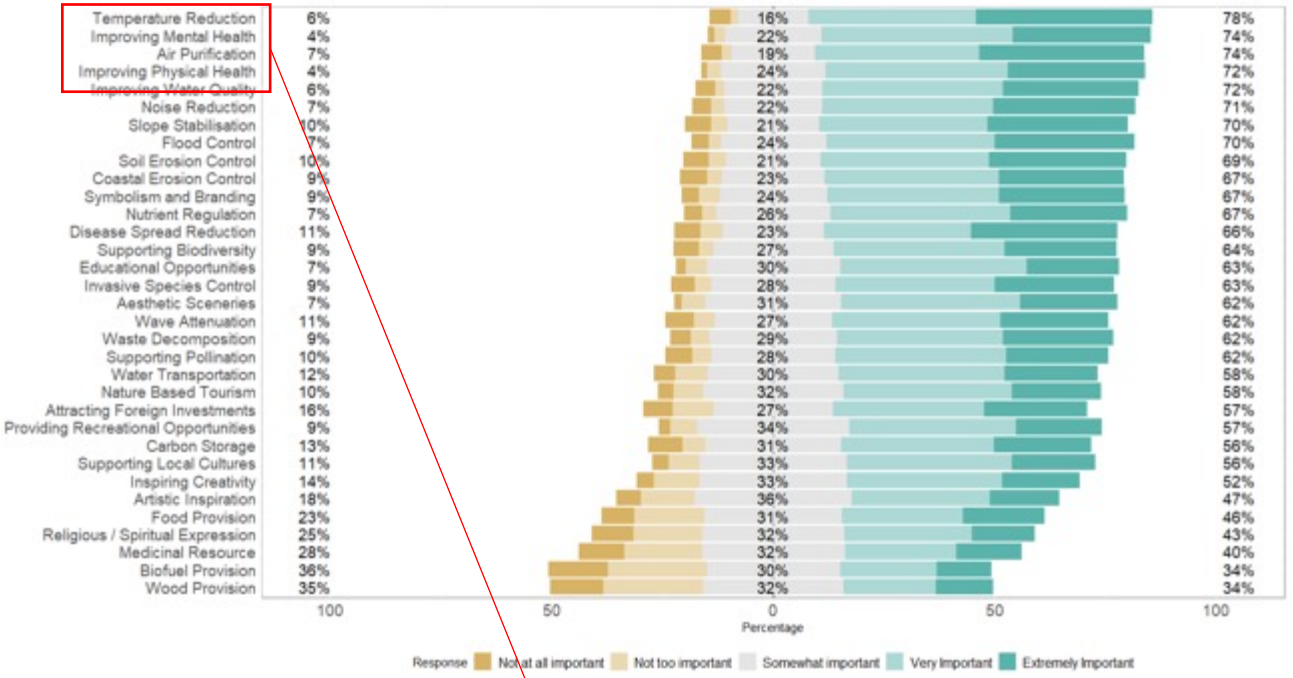
What ecosystem services do the public think are important?

Economic valuation:



Valued ecosystem services:
Increasing reduction in Temperature reduction & Air Purification met with corresponding increase in value

Social valuation:

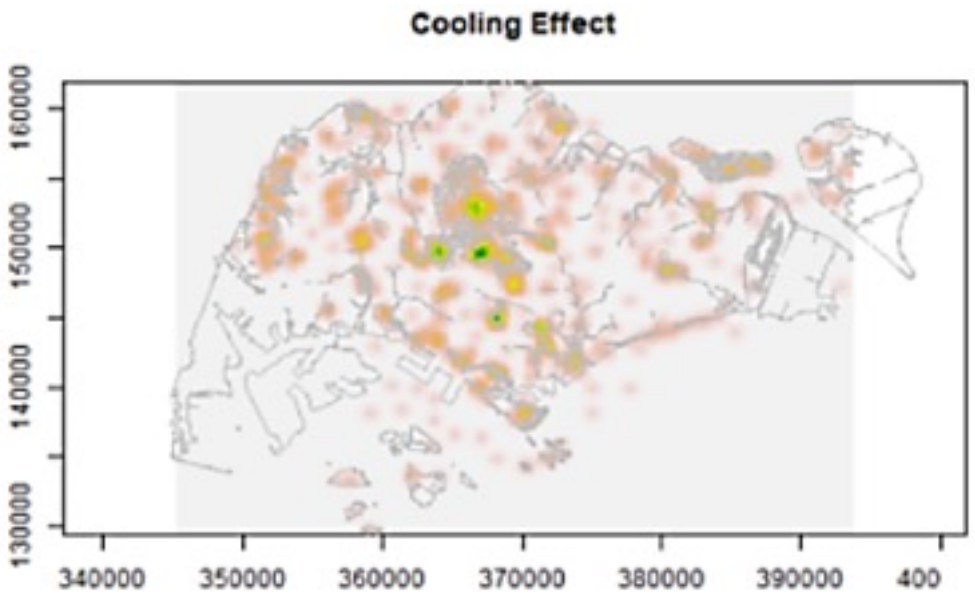


3 Most Important Ecosystem Services:
Temperature Reduction
Improving Mental Health
Air Purification

Perceptions and equity in ecosystem service provision

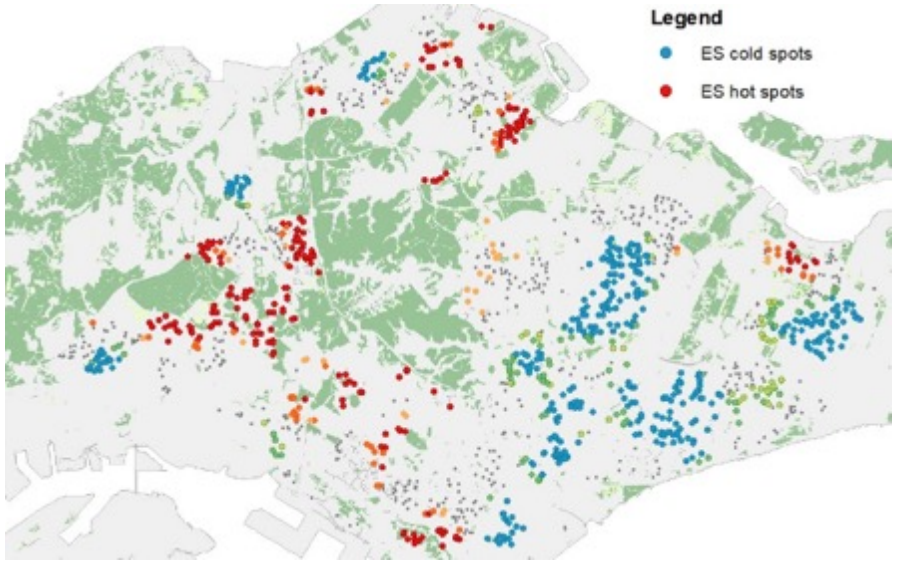
Perceptions

- Public perception of microclimate cooling is spatially random
- Perceptions of other services are spatially clustered (e.g., Nature Reserves)

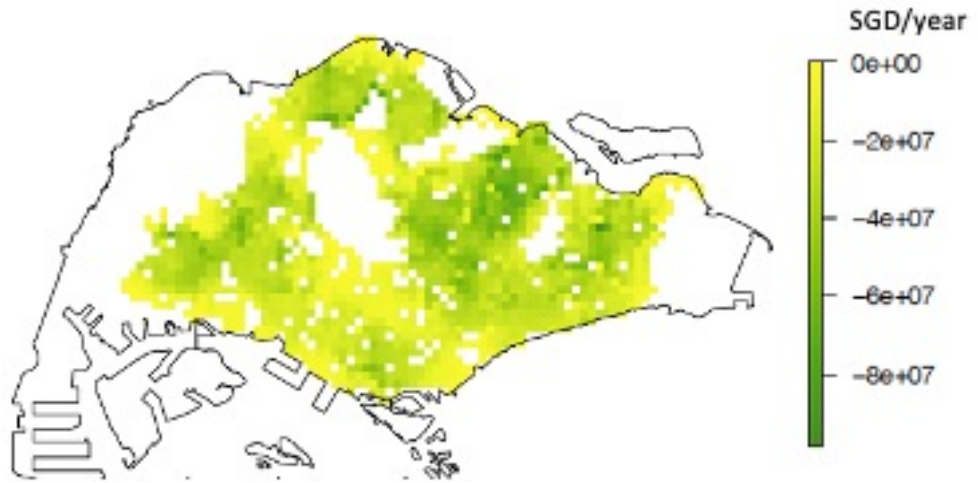


Equity

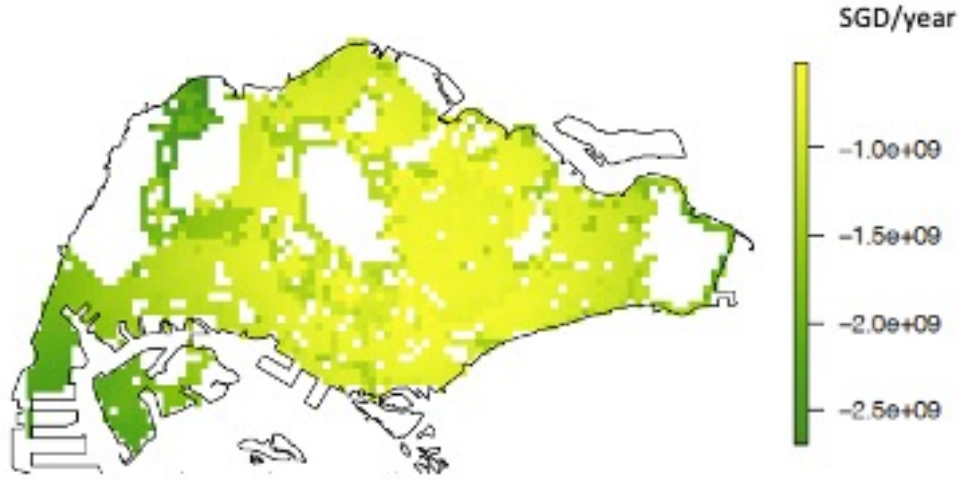
- Distribution of perceived services and actual services generally aligned spatially (except noise reduction)
- Ecosystem services are generally equitably distributed



Integrating economic values and ecosystem service distribution to inform park planning



Park value for neighborhood parks



Park value for non-neighborhood parks

Optimize new park locations for best ecosystem service provisioning, convenience and comfort

- Utilizing travel costs, economic valuation of temperature reduction, and crowd level estimations
  - High park value located in central of Singapore
- Information used can be updated to cater to different needs → Useful park planning tool

Key valuation take aways

- There is no single valuation – different ecosystem services have more appropriate ways of valuing, e.g., economic or societal

- The Public have strong views on what ecosystem services are more or less important
  - Air quality regulation and microclimate cooling have the highest economic and social value

- Demographically, ecosystem service provisioning is near-equitable
  - Microclimate cooling is spread out as trees are incorporated into streetscape
  - Other ecosystem services are concentrated where larger forested catchments are, indicative of their importance

- Information of valuation and ecosystem service distribution can be used to inform green space planning, e.g., park locations

- Other valuations, e.g., health, relational, are in progress!

Communicating our research

ST Three-year project will quantify benefits of Singapore's natural environment

>8 newspaper articles and opinion pieces

>5 TV news/documentary segments

>30 public and academic presentations

Lots of stakeholder engagement workshops

18 Journal papers published (and many more in progress!)

Communicating our data

- Terrestrial land cover: https://figshare.com/articles/A_high-resolution_map_of_Singapore_s_terrestrial_ecosystems/8267510
- R models for selected ecosystem services: https://figshare.com/articles/software/NCS2020_An_R_package_for_modelling_urban_ecosystem_service_provision_in_Singapore/13339055/1
- Links to published papers (including open access): http://naturalcapital.sg/outputs
- Other datasets and codes will be made freely available online as they are published

Summary

1. The Natural Capital Singapore project is the first comprehensive assessment of tropical urban natural capital in Singapore (and we think more broadly)

2. A unique collaboration between universities, research institutes and government

3. Singapore's natural and urban ecosystems provide a vast diversity of ecosystem services

4. The public and other stakeholders strongly value Singapore's ecosystem services

Natural Capital Singapore

www.naturalcapital.sg

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