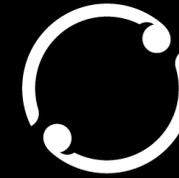


Ecosystem services for landscape planning and design

BIOECONOMY
SCIENCE
INSTITUTE



Manaaki Whenua
Landcare Research

Dan Richards

Senior Researcher and Research Priority Area Leader

richardsd@landcareresearch.co.nz

Kia ora!



UK



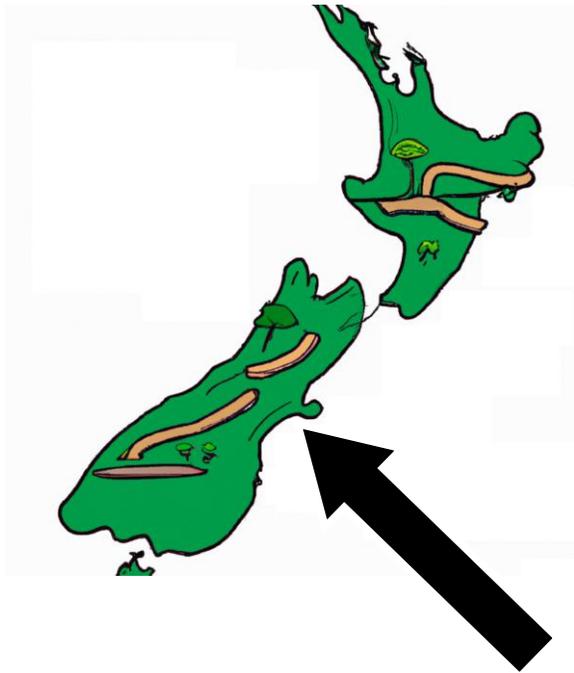
Singapore



New Zealand

Landscape ecologist
PhD from University of Sheffield 2014
Postdoc at National University of Singapore (2014-16)
Senior Researcher at ETH Zurich Future Cities Lab (2016-21)
Permanent position at Manaaki Whenua NZ (2021-present)

Kia ora!



BIOECONOMY
SCIENCE
INSTITUTE



Manaaki Whenua
Landcare Research

- New national research institute for environment, agriculture, forestry
- Formed on 1 July 2025
- ~2300 employees, 1600 researchers

Karakia



Piwakawaka
(fantail)

Let the strength and life force of the metaphysical
domain

Be with each and every one of us

Freeing our path from obstruction

So that our words, mana, love, and language are
upheld

Permanently fixed, established and understood!

Forward together

Ecosystem services for landscape planning and design

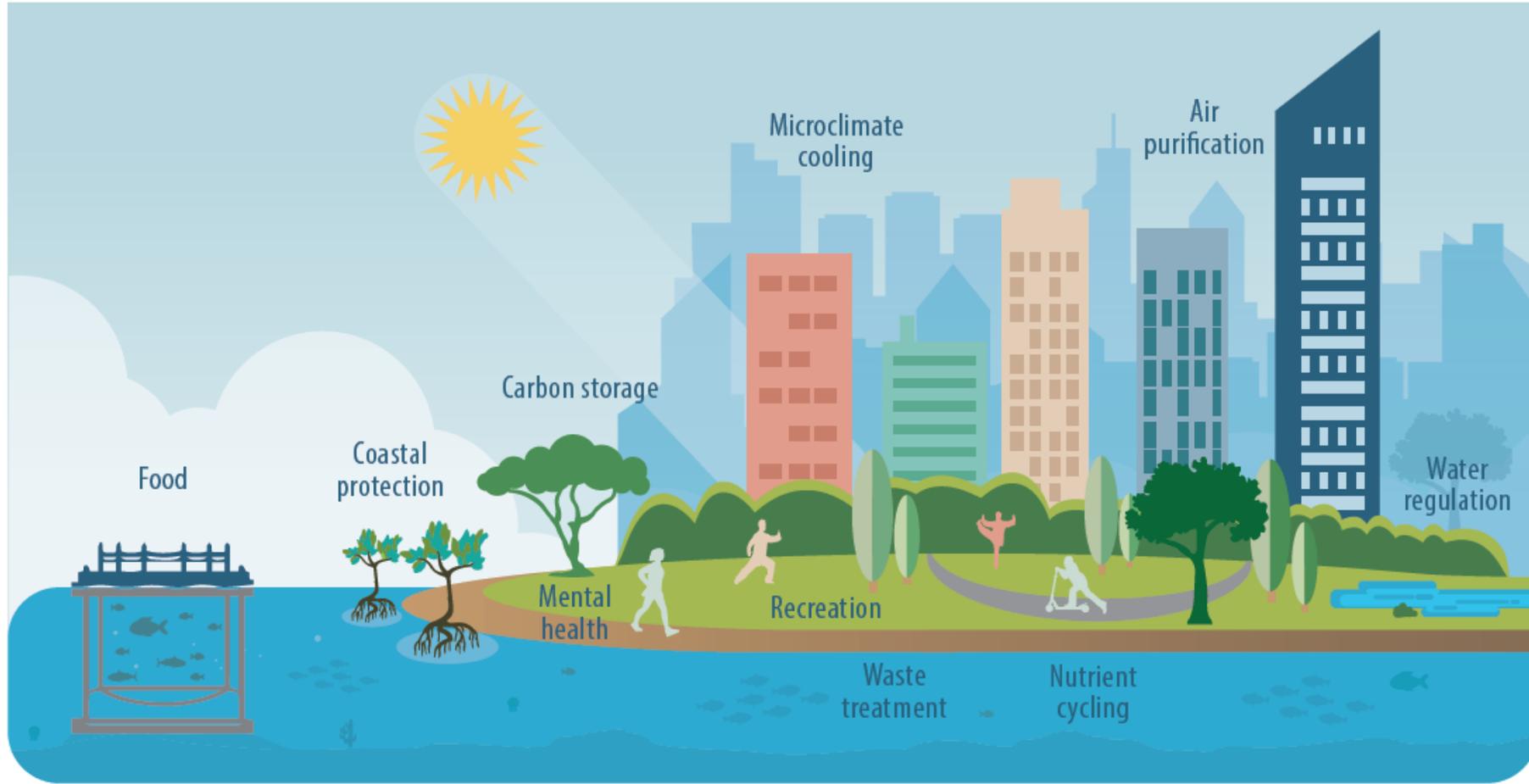


1. What are ecosystem services?
2. Measuring and mapping ecosystem services
3. Simulating future scenarios
4. Integration into planning and design

1. What are ecosystem services?



Nature provides us with numerous ecosystem services (benefits to people)



1. What are ecosystem services?

Ecosystem services are the benefits nature gives us



Provisioning services



Regulating services



Cultural services

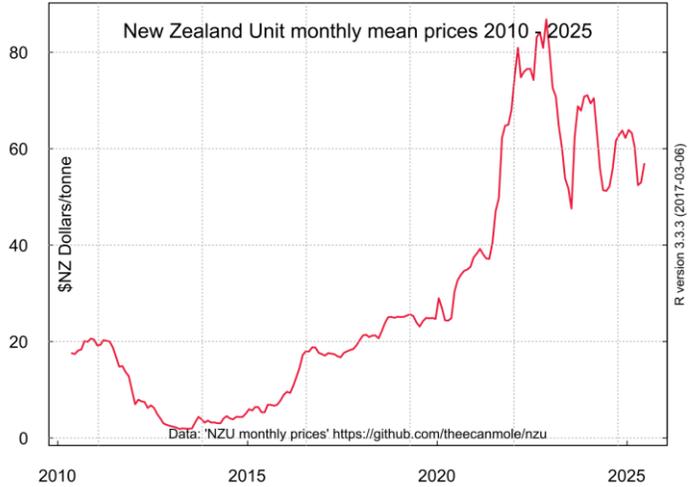


1. What are ecosystem services?

The importance of an ecosystem services perspective



Demonstrate the importance of nature



Avoid trade-offs



More sustainable futures



2. Measuring and mapping ecosystem services

Cooling effect of vegetation



2. Measuring and mapping ecosystem services



Cooling effect of vegetation



Turf



Tree over turf



Shrub



Tree with shrub
understorey

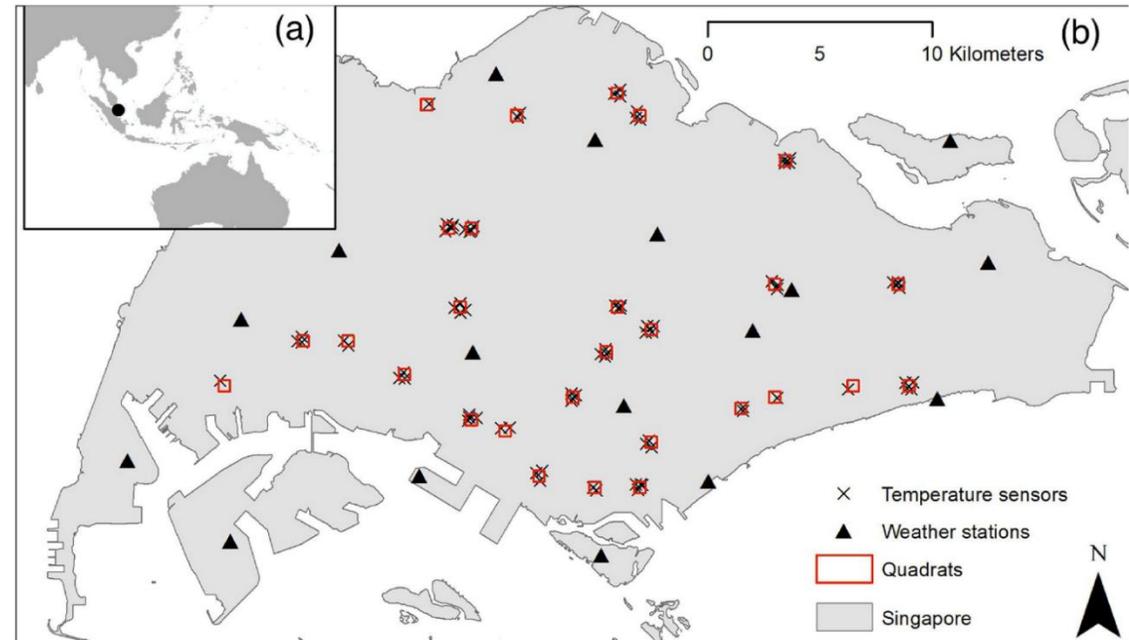


Unmanaged vegetation

Increasing structural complexity

2. Measuring and mapping ecosystem services

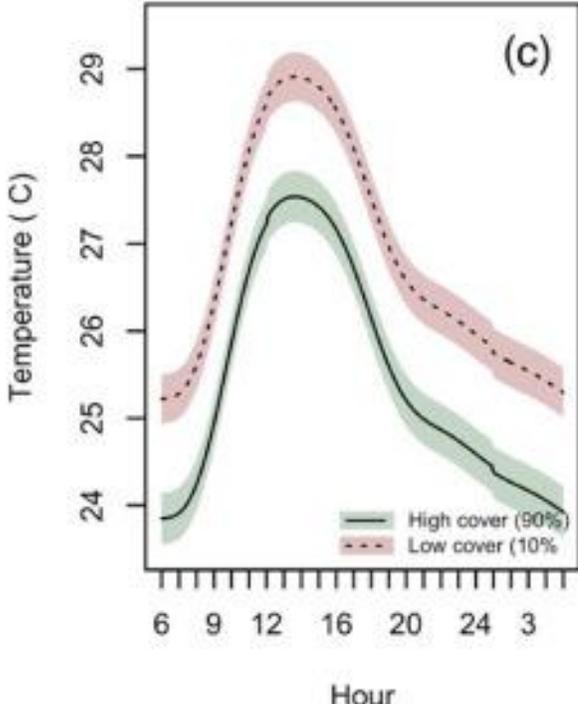
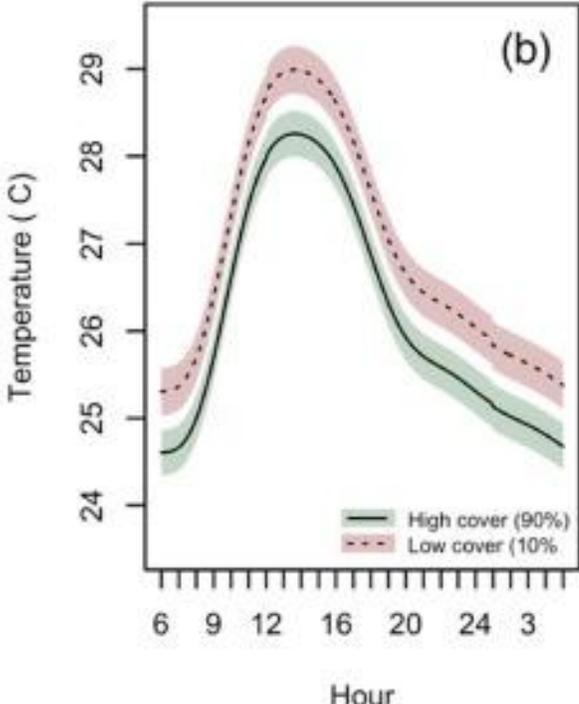
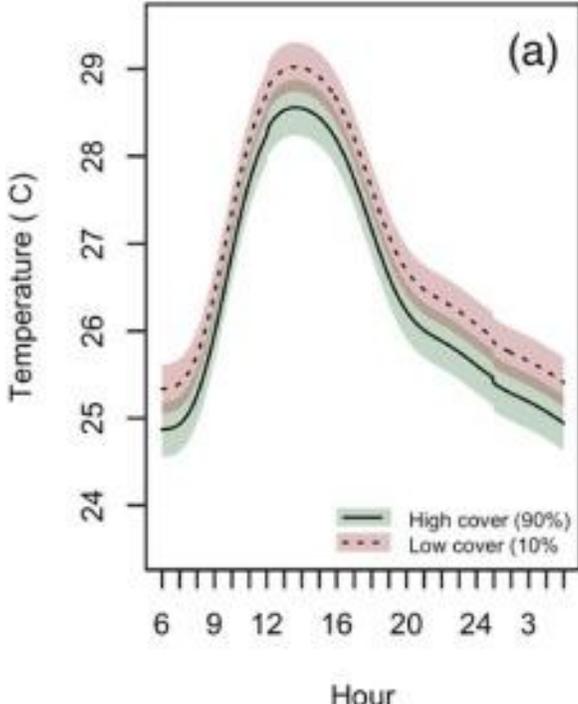
Cooling effect of vegetation



2. Measuring and mapping ecosystem services



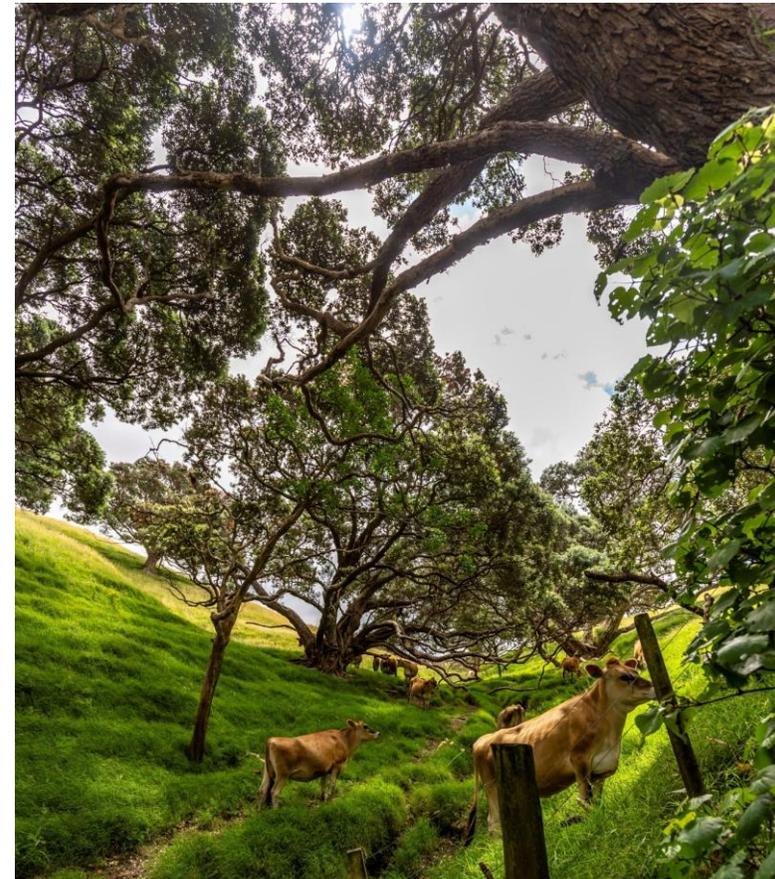
Cooling effect of vegetation



Richards et al. 2020, Urban Forestry and Urban Greening

2. Measuring and mapping ecosystem services

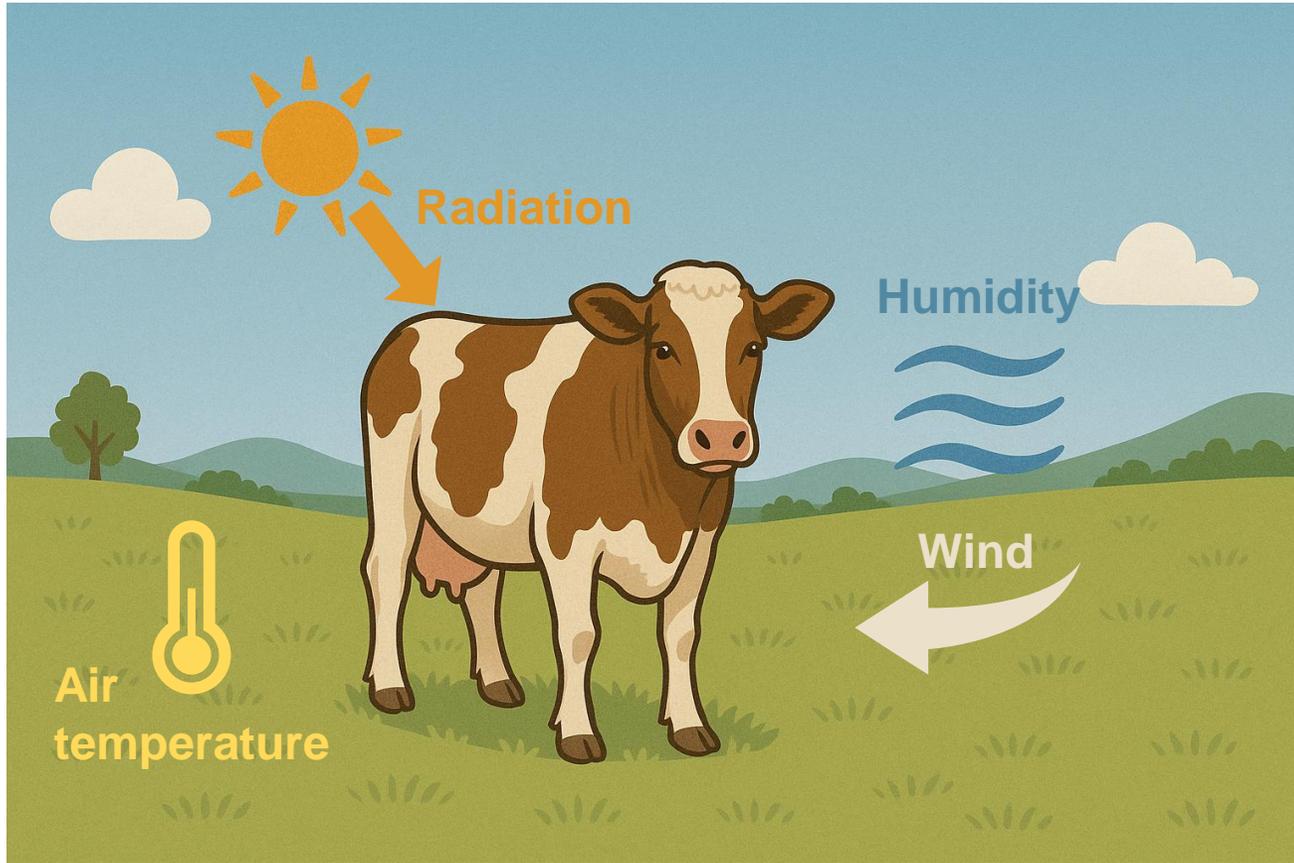
Tree benefits for livestock heat stress



2. Measuring and mapping ecosystem services



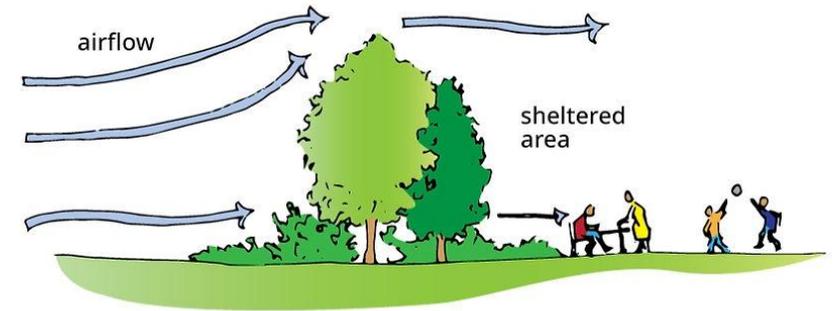
Tree benefits for livestock heat stress



Wind Humidity

Have relatively small impacts on heat stress

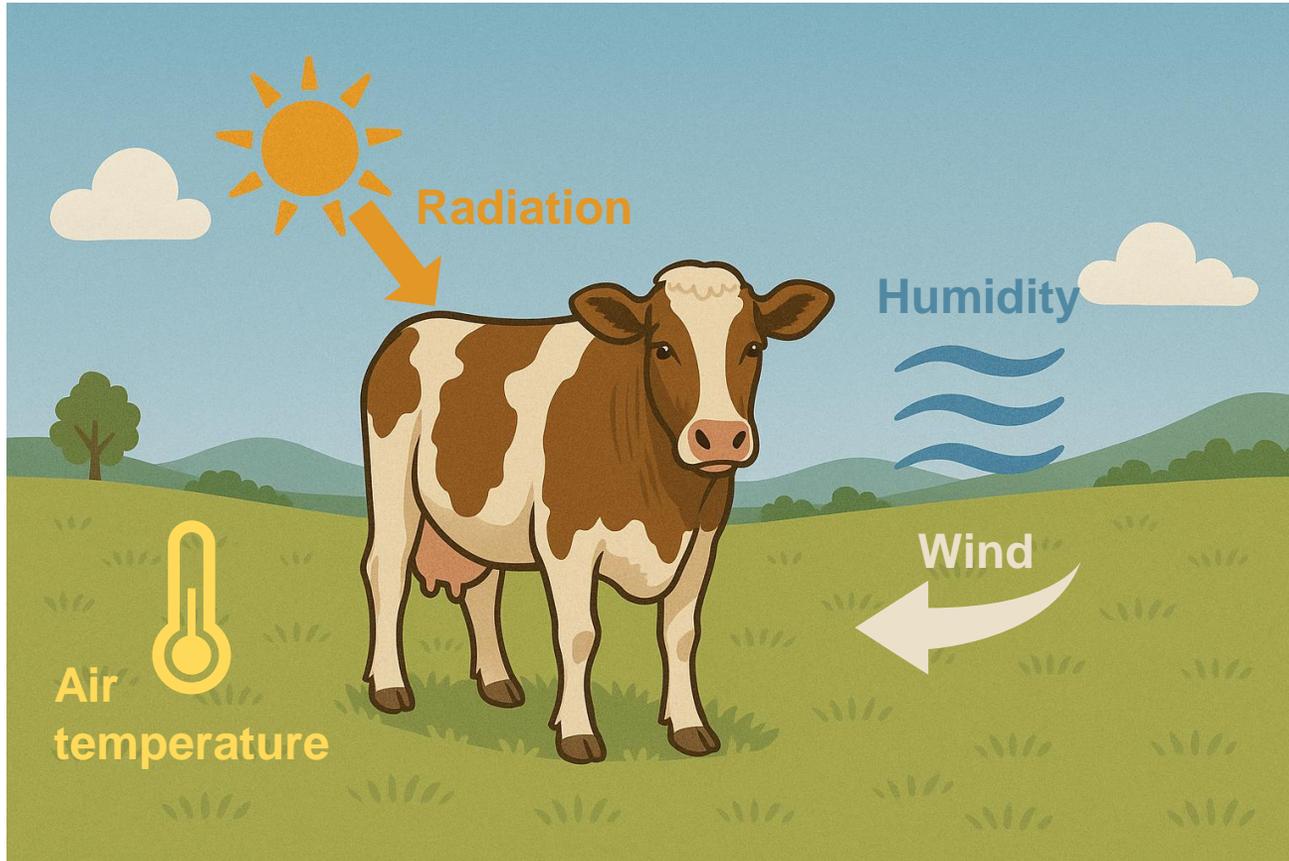
Direction varies depending on context and type of trees



2. Measuring and mapping ecosystem services



Tree benefits for livestock heat stress



Radiation

Large impact

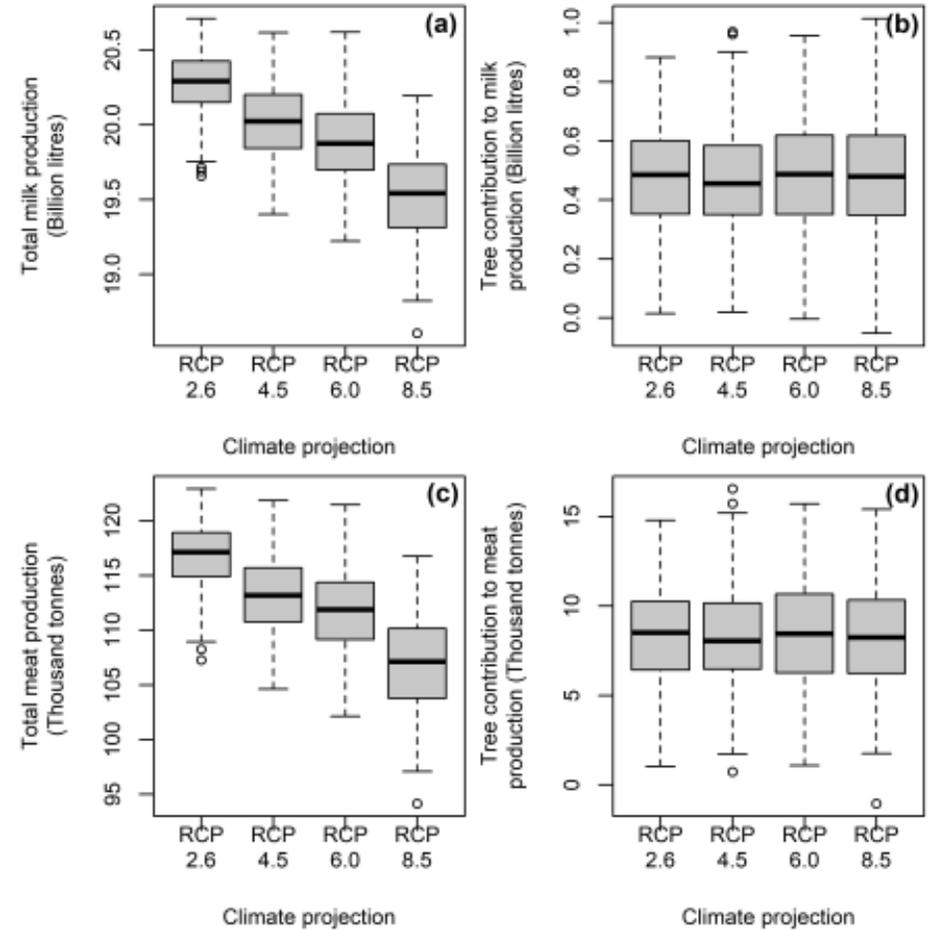
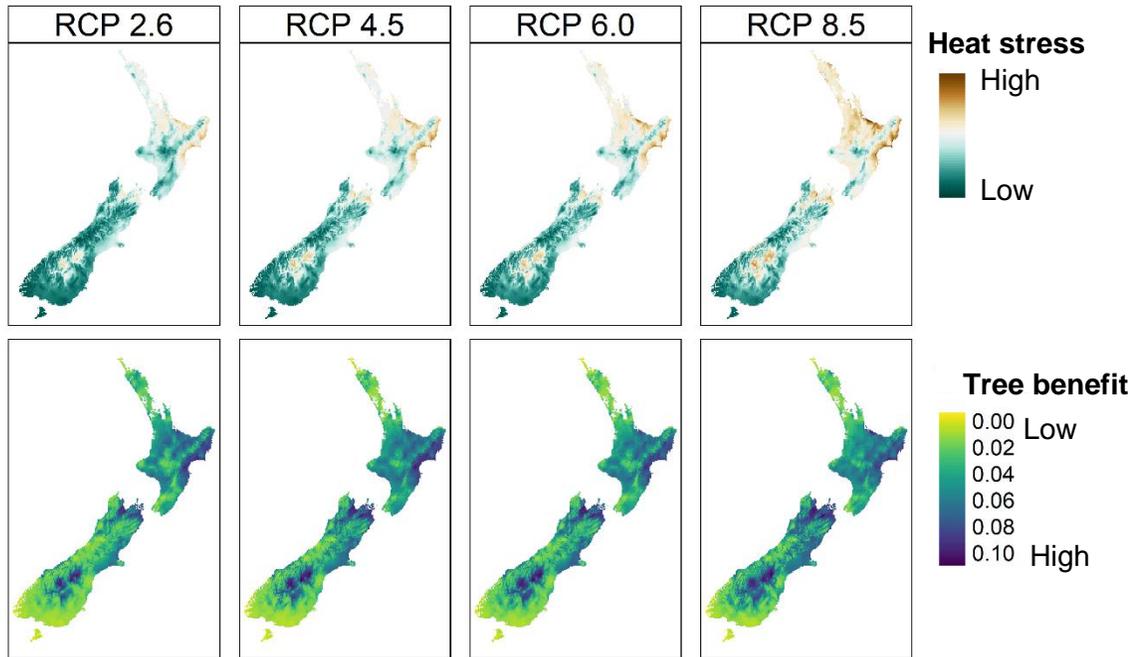
Always positive impacts

Air temperature

Large but variable

2. Measuring and mapping ecosystem services

Tree benefits for livestock heat stress



2. Measuring and mapping ecosystem services

Social media data as an indicator of recreational value



Song et al 2020. Land Use & Urban Planning
Song et al. 2020 Scientific Reports
Richards and Friess 2015. Ecological Indicators
Richards and Tuncer 2017. Ecosystem Services

2. Measuring and mapping ecosystem services

Social media data as an indicator of recreational value



Google Cloud Platform

Why Google Products Solutions Launcher Pricing Customers Documentation > TRY IT FREE

Labels Web Text Document Properties Safe Search JSON

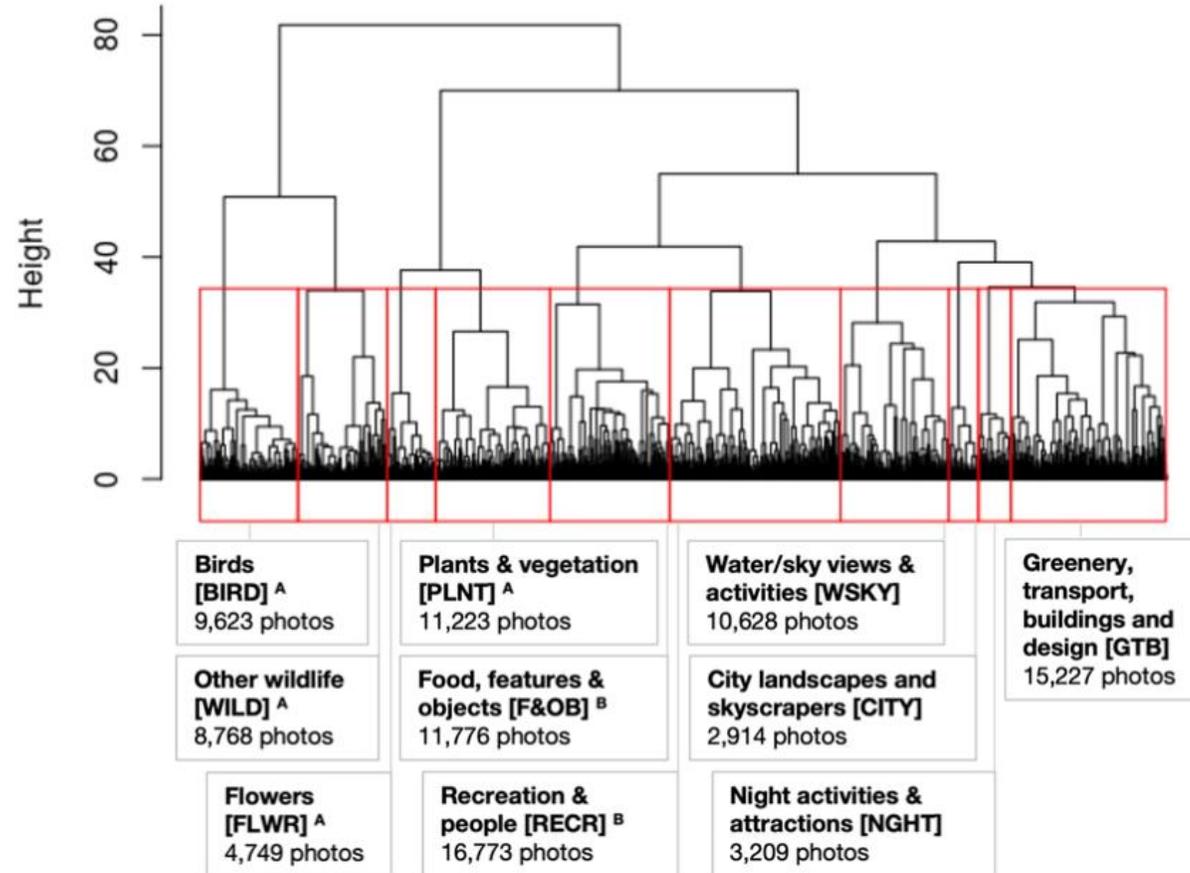
Tree	97%
Woody Plant	93%
Plant	89%
Architecture	80%
Leaf	78%
Campus	68%
Grass	58%

1. Extract geotagged images from social media
2. Infer content using machine learning image recognition

2. Measuring and mapping ecosystem services



Social media data as an indicator of recreational value

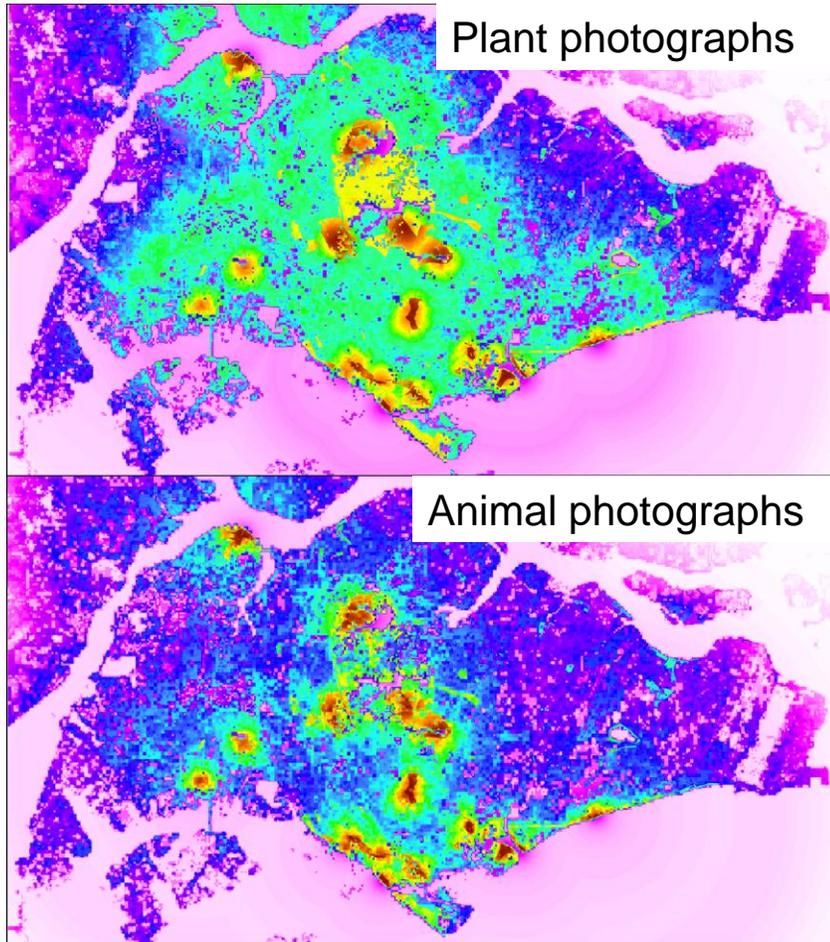


1. Extract geotagged images from social media
2. Infer content using machine learning image recognition

2. Measuring and mapping ecosystem services



Social media data as an indicator of recreational value



High : 1
Low : 0

Probability of photograph occurrence

0 5 Kilometres



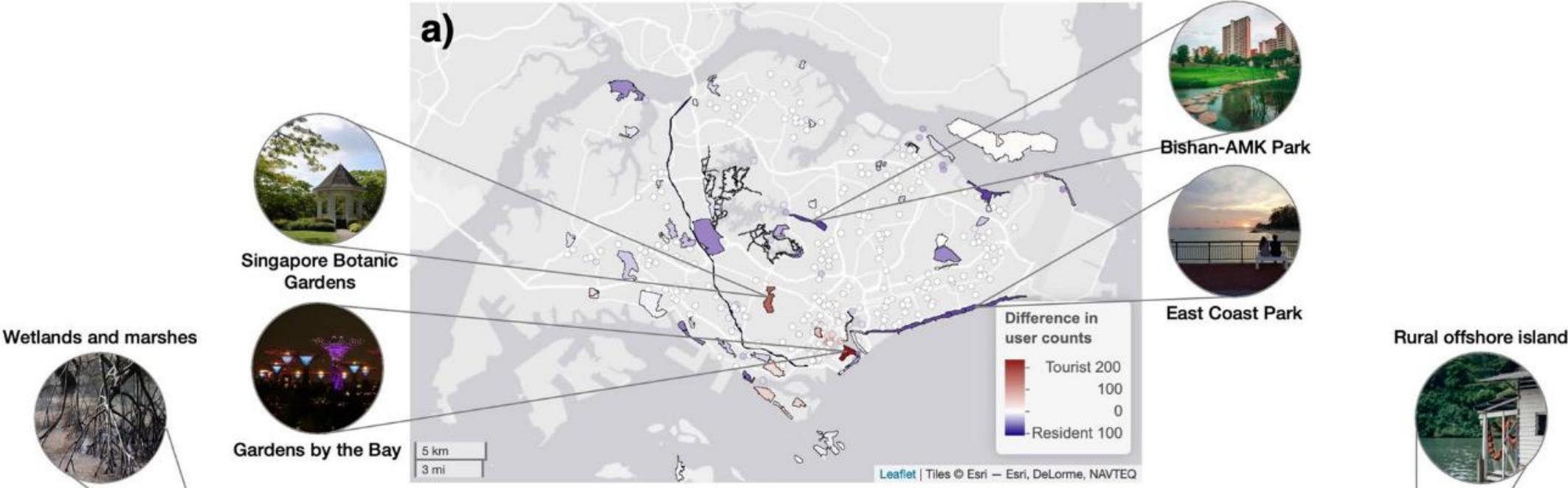
1. Extract geotagged images from social media
2. Infer content using machine learning image recognition
3. Model spatial occurrence in environment

Song et al 2020. Land Use & Urban Planning
Song et al. 2020 Scientific Reports
Richards and Friess 2015. Ecological Indicators
Richards and Tuncer 2017. Ecosystem Services

2. Measuring and mapping ecosystem services



Social media data as an indicator of recreational value



Song et al 2020. Land Use & Urban Planning
Song et al. 2020 Scientific Reports
Richards and Friess 2015. Ecological Indicators
Richards and Tuncer 2017. Ecosystem Services

3. Simulating future scenarios



Testing new scenarios: Tengah Forest Town

3. Simulating future scenarios



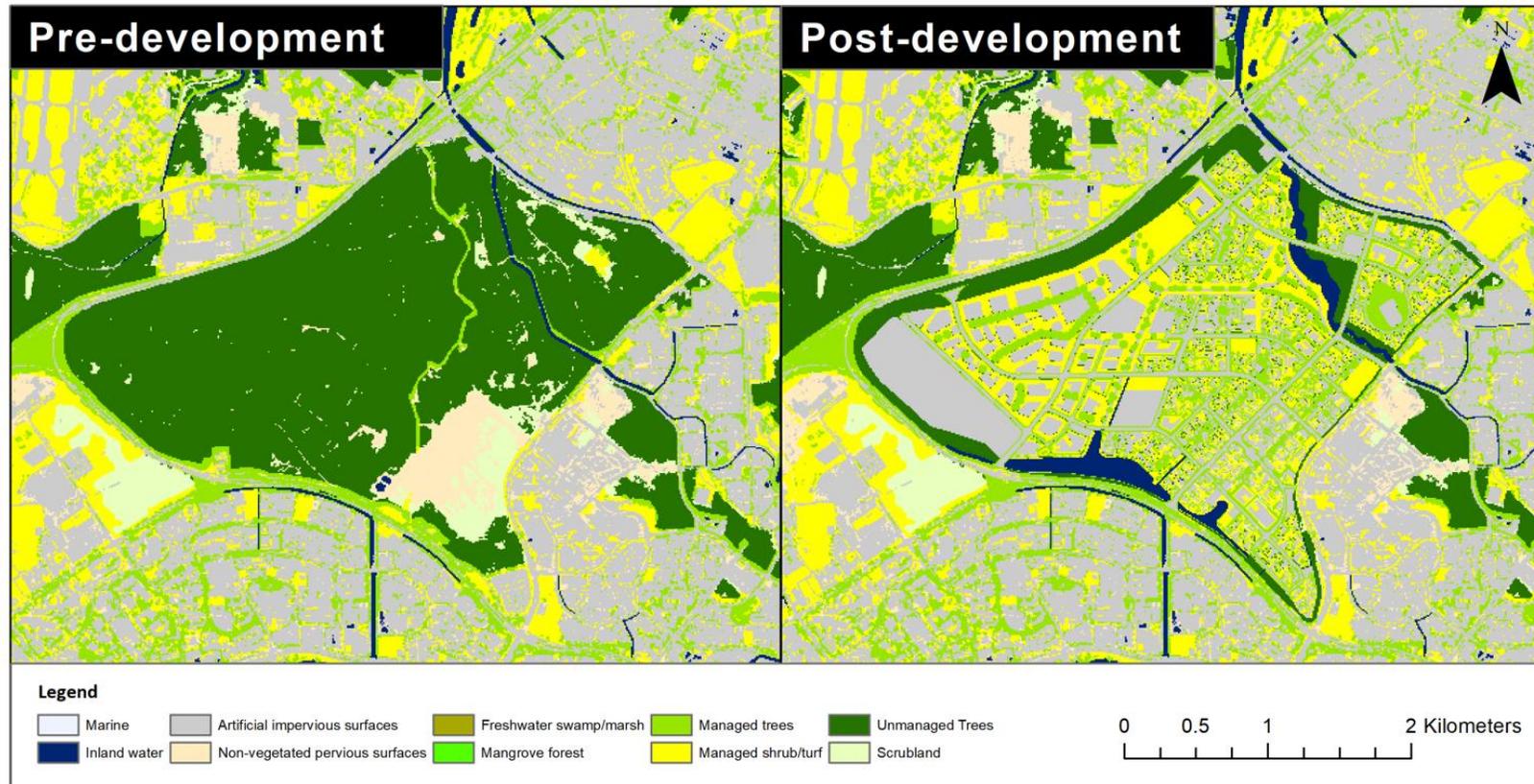
Testing new scenarios: Tengah Forest Town



3. Simulating future scenarios



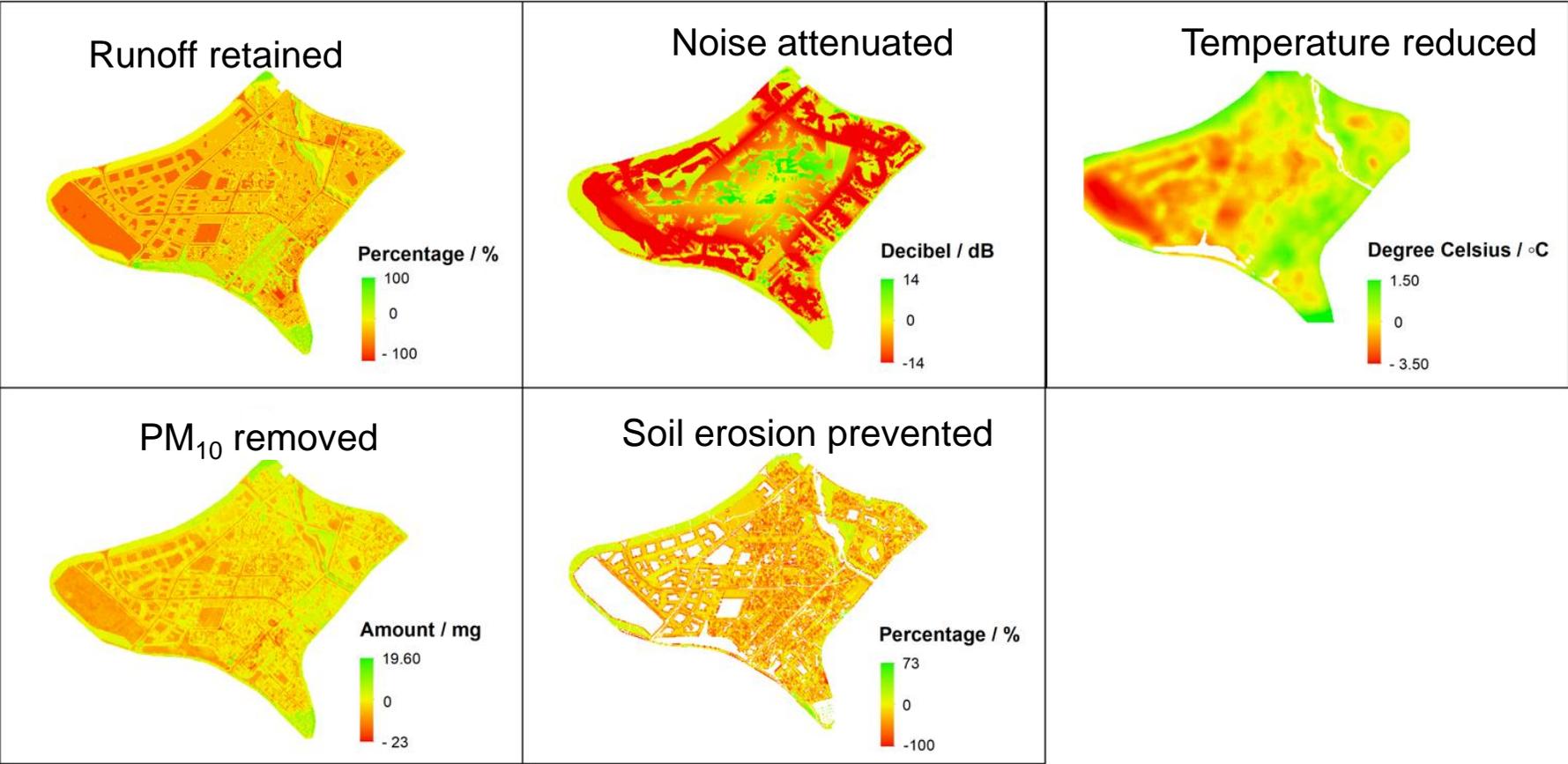
Testing new scenarios: Tengah Forest Town



3. Simulating future scenarios



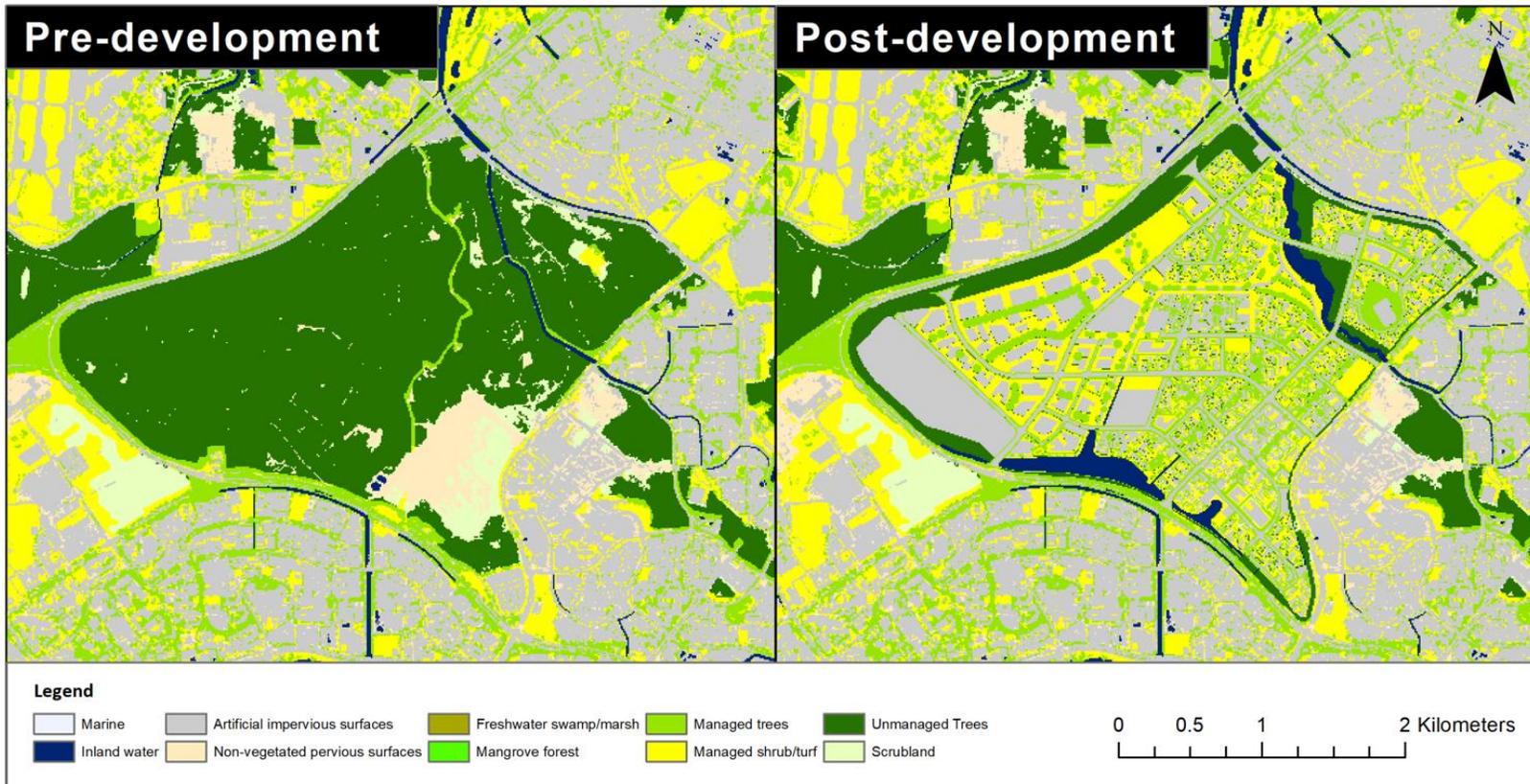
Testing new scenarios: Tengah Forest Town



3. Simulating future scenarios



2025 update: Tengah Forest Town



3. Simulating future scenarios



2025 update: Tengah Forest Town



3. Simulating future scenarios

Mackenzie Country, New Zealand

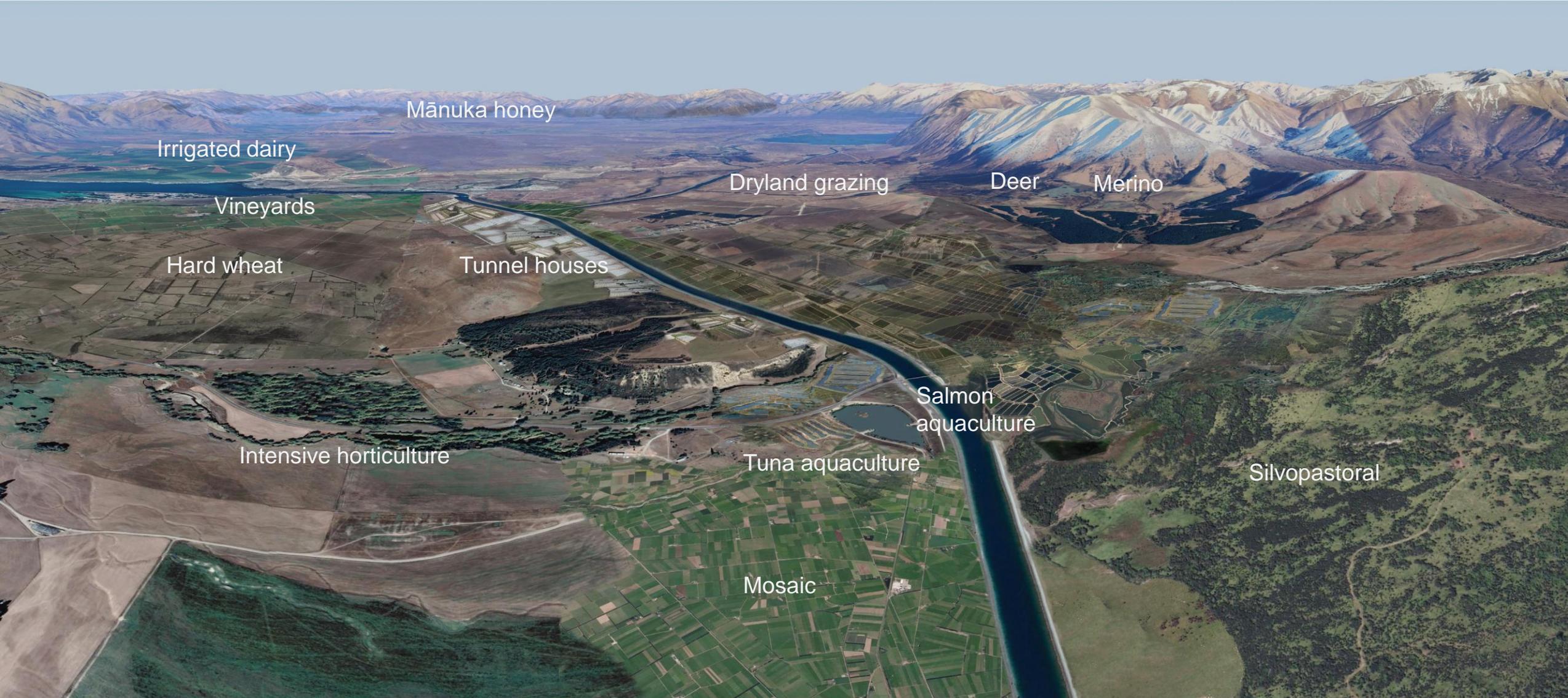


Lake Pukāki | Current Landscape

3. Simulating future scenarios



3. Simulating future scenarios



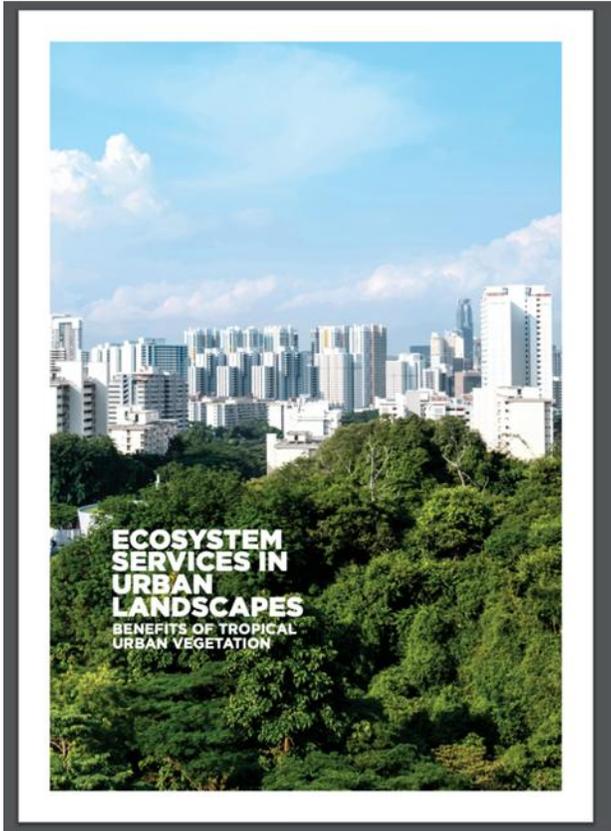
4. Planning and design



1. Guidelines and information
2. Software
3. Digital planning tools
4. Artificial intelligence

4. Planning and design

Guidelines and information



PART 2: SINGAPORE'S URBAN VEGETATION
Vegetation Types Highlighted in This Booklet

TREES OVER SHRUBS

This vegetation type consists of any combination of trees and shrubs that produces a canopy with two or more distinct layers. Two-layered vegetation is common along roadides and in HDB estates, with the lower layer consisting of either herbaceous plants or woody shrubs. More complex vegetation is to be found in the Nature Ways, that were first introduced by NParks in 2013. These multi-layered plantings along roadides are designed to imitate the structural complexity of natural forest, with emergent, mid-canopy, understorey, and undergrowth layers.¹⁰ A main aim of the Nature Ways is to provide green corridors connecting areas of high biodiversity. Plants species are chosen that provide food and shelter for animals, and the corridors are intended to help them move through the urban landscapes.

Species planted in trees over shrubs sites as part of Nature Ways include shrubs such as red tree-vine (*Leea rubra*) and Singapore rhododendron (*Melastoma malabathrum*), as well as trees such as *batoko glum* (*Flacourtia inermis*) and *kalat nai-nai* (*Syzygium zeylanicum*). Other common species that are incorporated into multi-layered vegetation planting are shrubs such as dwarf umbrella-tree (*Cochlospermum arborescens*) and red button ginger (*Costa woodsonii*).



Fig. 17 Shrubside planted with trees over shrubs. Photo Credit: Szeanne Chien

SPONTANEOUS VEGETATION

Spontaneous vegetation refers to plant communities that are not actively managed. This type of vegetation, colloquially called 'wild' vegetation, includes a few remaining areas of primary lowland rainforest and extensive areas of secondary forest that have developed and established without human intervention. Although these areas receive almost no pruning or soil enhancement, occasional interventions may be made to improve the quality of the vegetation and promote regeneration. It is also necessary to inspect and prune trees growing along edges and trees to ensure their safety and to prevent nearby infrastructure.




PART 5: GREEN SPACES FOR PEOPLE
How People Perceive Ecosystem Services and Disservices Provided by Urban Vegetation

HOW PEOPLE PERCEIVE ECOSYSTEM SERVICES AND DISSERVICES PROVIDED BY URBAN VEGETATION

To plan and manage green spaces effectively, it is important to understand how people perceive and value these areas. Reported consultations with members of the public can reveal how perceptions change with time¹¹, which can be useful in designing green spaces that continue to meet people's needs¹².

We conducted an online survey to quantify how urban vegetation services and disservices were perceived by residents in Singapore. The survey also explored which types of urban vegetation were considered most important in providing these services and disservices. The survey was conducted in 2016 and was restricted to 1,000 Singapore residents.

The results show that residents perceived ecosystem services provided by urban vegetation to be considerably more important than possible disservices¹³. Services that influenced environmental conditions (regulating ecosystem services) were considered more important than those with a cultural or social impact (cultural ecosystem services). The regulating services that were most valued were those contributing to shade, air quality and flood regulation. Among the cultural ecosystem services, benefits related to improved aesthetics, well-being and positive interactions with wildlife were highly appreciated. More than 80% of answers about disservices concerned problems of pest and disease.

Survey participants also stated the types of vegetation they would like to see more of in their neighbourhood. The most preferred types were trees, grass, and trees over shrubs; these were followed by secondary forest, and finally by shrubs.

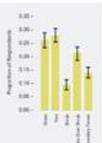
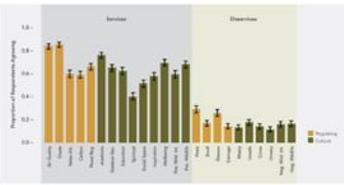



Fig. 20 Proportion of the proportion of ecosystem services and disservices of vegetation in Singapore in 2016¹⁴.

Vegetation Type	Top 3 most commonly associated Ecosystem Services	Top 3 most commonly associated Ecosystem Disservices
Grass	Shade, Air quality, Outdoor recreation, Well-being	Pest, Soil, Disease
Shrubs	Aesthetics, Inspiration, Well-being	Soil, Pest, Disease
Trees	Air quality, Cooling, Noise attenuation	Property damage, Safety hazard, Money
Trees over shrubs	Aesthetics, Inspiration, Outdoor recreation	Property damage, Pest, Soil
Secondary forest	Positive wildlife interactions, Education, Carbon storage	Money, Climate, Pest

Table 3 Proportion of the urban vegetation types that were most valued for providing ecosystem services and disservices. The most valued ecosystem services and disservices are highlighted in Singapore.

Fig. 21 Types of vegetation that were most valued for providing ecosystem services and disservices in Singapore in 2016¹⁵.

Guide for landscape architects available free here:
https://ethz.ch/content/dam/ethz/special-interest/dual/fcl-dam/doc/LR_FCL_Benefits_of_Tropical_Urban_Vegetation_050820.pdf

4. Planning and design

Software



Air Temperature Model

Impact of vegetation cover on air temperature



Noise Model

Impact of vegetation on attenuation of road traffic noise



PM10 Model

Impact of vegetation in removing particulate matter air pollution



Runoff Model

Impacts of ecosystems in retaining runoff



Access Model

Access of people to green and blue spaces for recreation



Soil Erosion Model

Impact of ecosystems in preventing soil erosion

<https://github.com/drexrichards/ncs2020>

4. Planning and design

Software



```
RStudio File Edit Code View Plots Session Build Debug Profile Tools Window Help
~/Documents/Dan's r packages/ncs2020 - master - RStudio
runoff.R x noise.R x
Source on Save Run Source
1 #' Modelling of runoff absorbtion by vegetation
2 #'
3 #' This function models runoff reduction by vegetation
4 #' @param lcm Land/ water cover map, including vegetation categories.
5 #' @param rainfallin Rainfall in mm
6 #' @return Two rasters in a list, the first is proportion of runoff a
7 #' @export
8 runoff.model <- function(lcm, rainfallin){
9   # make a new raster of curve numbers
10  cnras <- raster::reclassify(lcm, data.frame(ncs2020::looktbl$gaw.20
11
12  # estimate runoff for a given rainfall event
13  # lets assume a 110 mm hourly rainfall event
14  # this is a big storm in Winston Chow's Singapore flooding paper
15  # 15 inches = 381 mm. so 1 is 25.4
16  # 50 mm is 1.96 inches
17
18  rain <- 0.03937008 * rainfallin
19
20  # see if it matches first
21  if(rain %in% runoffcurve$Rainfall){
22    nrunoff <- runoffcurve[which(runoffcurve$Rainfall == rain),]
23
24  } else {
25
26  # First find the index between we are between
10:27 runoff.model(lcm, rainfallin) R Script
Console ~/Documents/Dan's r packages/ncs2020/
> ?ncs2020
No documentation for 'ncs2020' in specified packages and libraries:
you could try '??ncs2020'
> |
```

drexrichards / ncs2020 Private

Unwatch 1 Star 0 Fork 0

Code Issues 0 Pull requests 0 Actions Projects 0 Wiki Security 0 Insights Settings

No description, website, or topics provided. Edit

Manage topics

11 commits 1 branch 0 packages 0 releases 1 contributor

Branch: master New pull request Create new file Upload files Find file Clone or download

File	Access	Latest commit
R	Corrected green access	9 days ago
data	Corrected green access	9 days ago
man	This version includes a tested and working noise model. Unfortunately...	27 days ago
.Rbuildignore	initial commit	2 months ago
.gitignore	initial commit	2 months ago

Modelling ecosystem ser

Documentation for package 'ncs2020' version 0.1.0

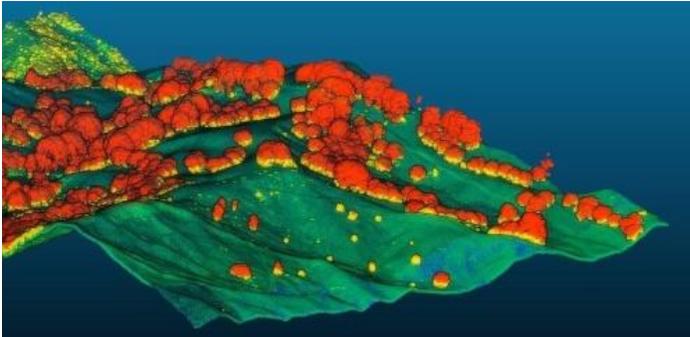
- [DESCRIPTION file.](#)

Help Pages

access.model	Modelling of public access to green space and natural ecosystems and open water
air.temp.model	Modelling of reduction in air temperature caused by ecosystems
hello	Hello, World!
noise.model	Modelling of noise attenuation by vegetation
pm10.model	Modelling of PM10 removal by vegetation
runoff.model	Modelling of runoff absorbtion by vegetation
soilerosion.model	Modelling of soil erosion protection by ecosystems
soilK.model	Calculation of soil K factor based on soil data

4. Planning and design

Software



GitHub repository page for `manaakiwhenua/hbrc`. The repository is public and contains 24 commits. The commit history shows updates to the README, data, and documentation.

Commit	Message	Time
drexrichards	Update README.md	8 months ago
R	Minor error in cn.e1	8 months ago
data	Removed datasets from data since they do not travel well. T...	8 months ago
man	Updated to match Beets et al 2012 Table 2	9 months ago
.Rbuildignore	Initial	9 months ago
.gitignore	Initial commit	9 months ago
DESCRIPTION	Addition of pdf guide version	9 months ago
LICENSE.md	Initial	9 months ago
NAMESPACE	Initial commit	9 months ago
README.md	Update README.md	8 months ago
hbrc.Rproj	Initial commit	9 months ago
intro-hbrc-v3.pdf	Updated documentation after fixing biomass	9 months ago

About
Functions for estimating ecosystem services indicators using high-resolution spatial datasets.

Releases
No releases published

Packages
No packages published

Languages
R 100.0%

hbrc: Quantifying ecosystem services

<https://github.com/manaakiwhenua/hbrc>

4. Planning and design



Software

<https://github.com/manaakiwhenua/hbrc>

Introduction to the HBRC package

Dan Richards

2023-12-04

Contents

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Package installation and set-up	2
Package functions summary	2
Runoff retention	2
Carbon stocks	2
Air pollution removal	3
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Shade	3
Nutrient retention	3
Example usage	4
Test case study region	4
Runoff retention	6
Aboveground biomass carbon stocks	8
Air pollution removal	10
Ultraviolet (UV) protection	12
Shade	13
Landscape aesthetics	15
Nutrient retention	17
Uncertainty propagation	18
Saving output maps	20
Acknowledgements	21

4. Planning and design



Software

<https://github.com/manaakiwhenua/hbrc>

Introduction to the HBRC package

Dan Richards

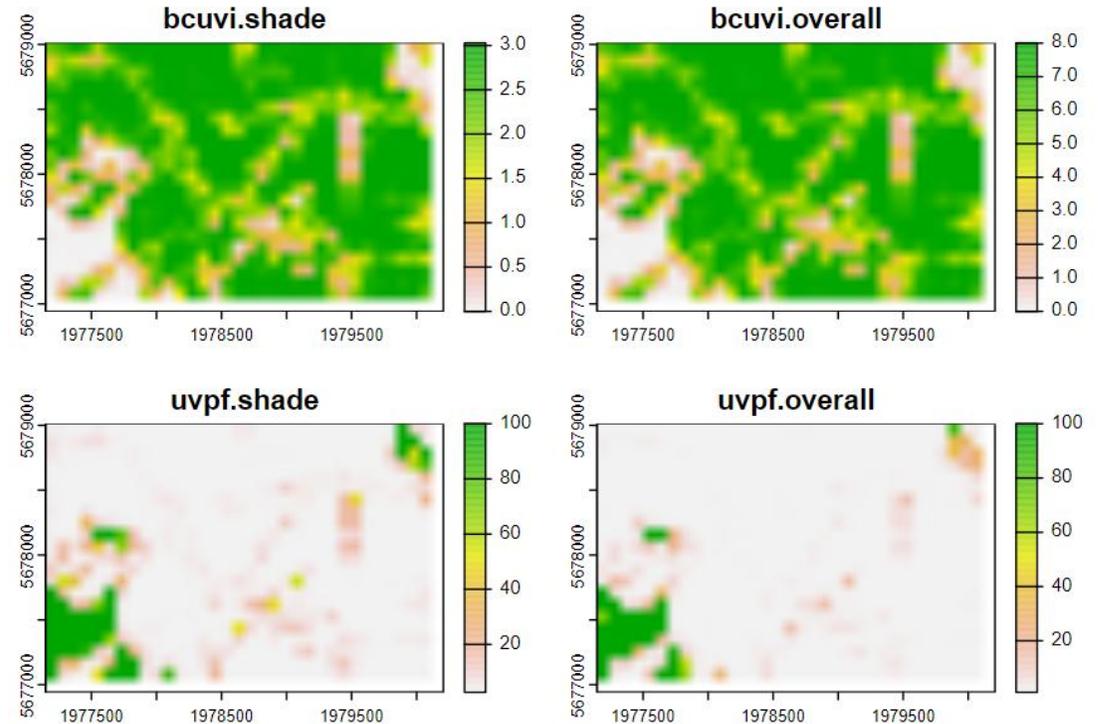
2023-12-04

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Shade	13
Landscape aesthetics	15
Nutrient retention	17
Uncertainty propagation	18
Saving output maps	20
Acknowledgments	21

```
# Run function
uv.out<- hbrc.uv(lcm=hb.1m$hb.lcm,
                 chm=hb.1m$hb.chm,
                 ccutoff=1.6,
                 uvi=8,
                 sza=25,
                 resc=100,
                 ltb = hb.eslookup[,c(2,12)],
                 skc="CLR")

plot(uv.out)
```



4. Planning and design

<https://mwlr.nz/ncp-christchurch>

Digital planning tools



Benefits of urban vegetation in Ōtautahi/ Christchurch Manaaki Whenua/Landcare Research | Full Report and data

Layer List

- Green spaces for education
- Carbon stock
- Particulate matter removed
- Distance to public recreation space
- Bird species
- Private green space
- Shade provision
- Runoff retained
- Erosion prevented

POWERED BY esri

LINZ, Stats NZ, Esri, HERE, Garmin, Foursquare, METI/NASA, USGS | LINZ, Stats NZ, Esr...

4. Planning and design

Digital planning tools <https://www.selwyn.govt.nz/news-And-events/news/mapping-the-blue-green-benefits-of-ecosystem-services-in-rolleston>



Rolleston Ecosystem Services Case Study

The case study is part of a broader research programme on the Waikirikiri Ki Tua Future Selwyn Blue-Green Network

4. Planning and design



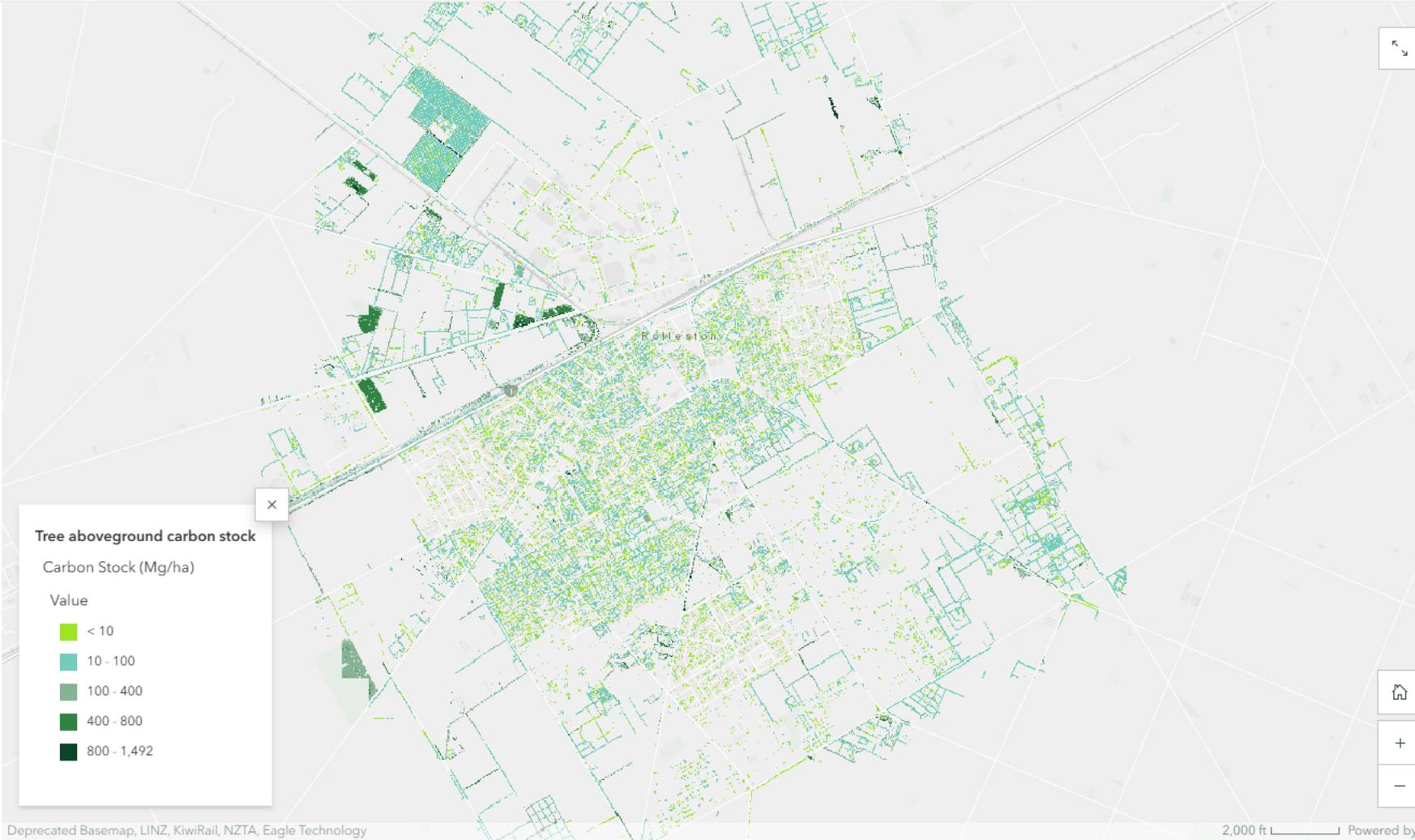
Digital planning tools

Carbon stock in tree aboveground biomass

Carbon dioxide is Earth’s most important greenhouse gas that absorbs and radiates heat. The more trees we have, the more carbon is removed from the atmosphere which plays a crucial role in mitigating climate change as increased carbon dioxide in the air traps some of the heat that Earth would otherwise radiate into space, resulting in warmer climates and contributing to the greenhouse effect.

Fossil fuels that are burnt for energy are the largest contributor to increasing concentrations of carbon dioxide in the atmosphere. As we are producing more carbon dioxide than the amount that natural carbon sinks (such as the land and oceans) can remove, the total amount of carbon dioxide in the atmosphere increases every year.

Carbon is stored in trees through the process of photosynthesis where carbon dioxide is absorbed from the air and converted into



4. Planning and design

Artificial intelligence

Automated reports
84 cities around the world

1 Scope
2 Executive summary
3 Current environment
4 Climate Change Impacts
5 Future Opportunities
6 Methods
7 References

Urban ecosystems of Dunedin

Dan Richards

Manaaki Whenua - Landcare Research, Aotearoa New Zealand
richardsd@landcareresearch.co.nz

1 Scope

This report was written as part of a research project aiming to make information on urban ecosystems available to the residents of towns and cities worldwide. The maps and data presented in this report are the output of a global data synthesis and simulation exercise, so necessarily rely on global datasets that may not be the most up-to-date or spatially precise for the location. The analysis fused petabytes of publicly available spatial data from more than 15 datasets, and applied global models for urban ecosystem services. More details and relevant references for further reading can be found in the Methods section. The intention of these reports is to provide a standardised minimum level of understanding of the structure and services provided by urban ecosystems in Dunedin. We encourage the reader to search for any local reports or research that may exist, as these are likely to be more accurate and relevant to the local context. The authors take no responsibility for the quality and accuracy of the data, models, or text provided in this report. The report should not be solely relied on for decision-making.

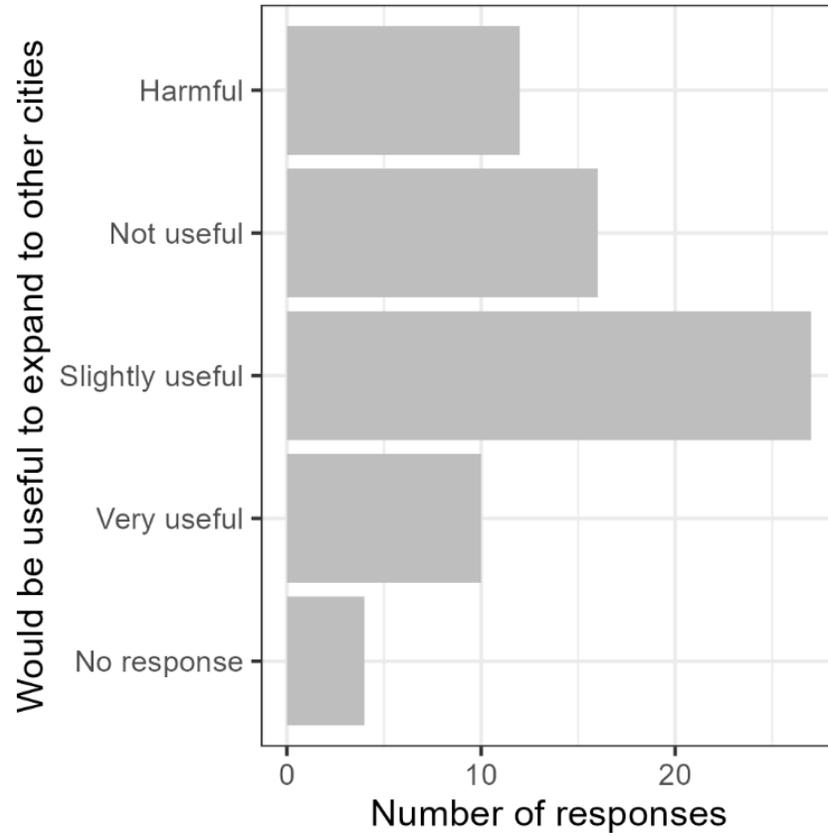
2 Executive summary

- **Urban Biodiversity:** Dunedin's urban ecosystems are characterized by diverse vegetation, bird species, and other animal life. The city's greenspaces, including parks, street trees, and private gardens, host a range of native and exotic plants, contributing to substantial botanical diversity. Bird species such as the red-billed gull, southern black-backed gull, and tui are emblematic of this rich avian life, while mammals like the New Zealand sea lion and hedgehogs highlight the city's ecological variety beyond avifauna.
- **Ecosystem Services:** Dunedin's urban ecosystems provide critical services, enhancing both environmental and human health. Key regulating services include significant flood protection, where vegetation mitigates approximately 53.4% of incoming rainfall during high precipitation events and prevents 77.6% of potential soil erosion. Temperature regulation through shade from urban trees significantly reduces solar radiation, contributing to thermal comfort and reduced energy demand. Urban ecosystems also play a vital role in carbon sequestration, storing 339,386 megagrams of carbon and sequestering 10,279 megagrams annually.
- **Socio-cultural and Provisioning Services:** Residents benefit from high accessibility to green spaces, with 97.5% living within a five-minute walk of an urban ecosystem, which supports recreation and physical and mental health. Cultural values are intrinsically linked to these ecosystems, particularly through Māori traditions and the celebration of native bird species. Urban agriculture, including community gardens and peri-urban farming, contributes to local food security and social well-being, supplementing household nutrition and fostering community engagement.
- **Climate Change Impacts:** Climate projections suggest Dunedin will experience increased temperatures (0.7 to 1.7 degrees Celsius rise) and variability in precipitation patterns, posing threats to urban ecosystems such as vegetation stress and heightened urban heat island effects. However, urban ecosystems act as buffers against climate impacts by



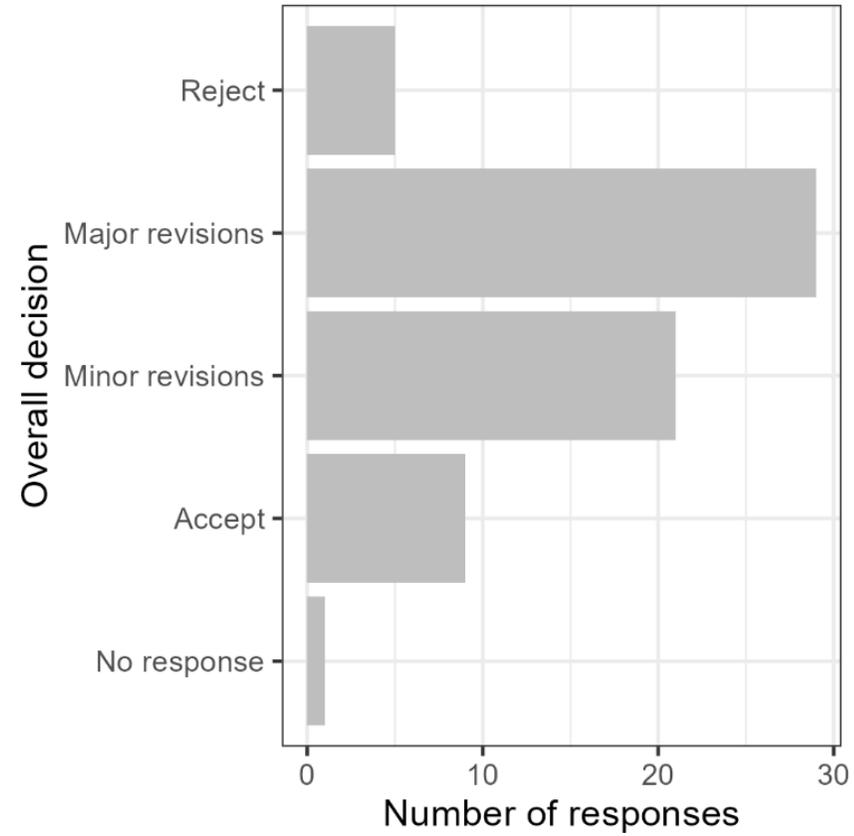
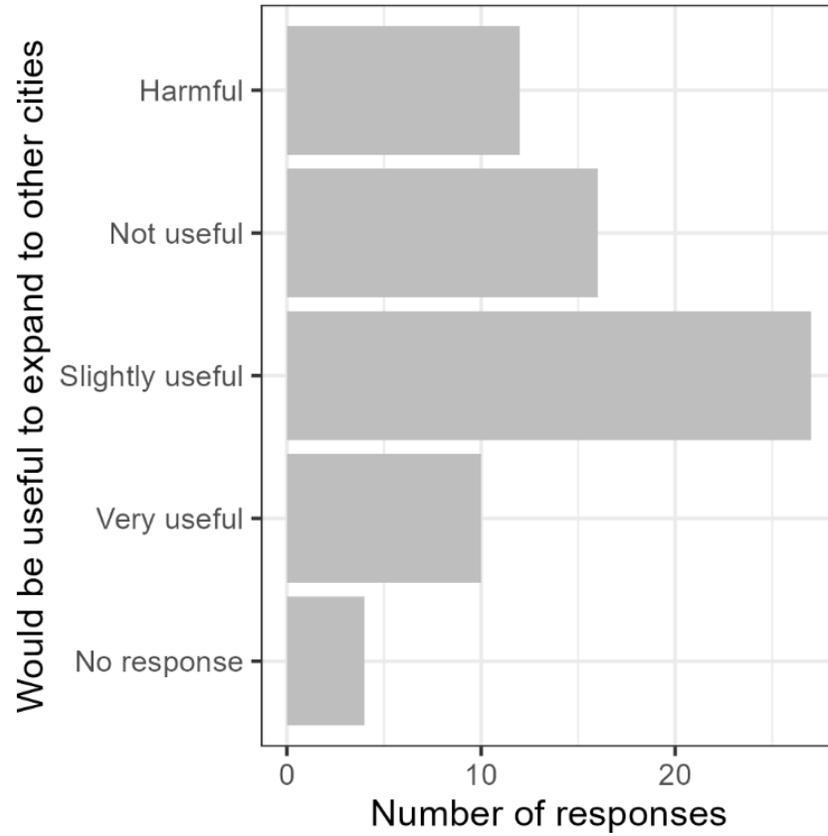
4. Planning and design

Artificial intelligence



4. Planning and design

Artificial intelligence



4. Planning and design

Artificial intelligence



Climate & Agriculture Gen AI System

Disconnected

Clear

Export



Climate and Agriculture Agent

Ask questions about climate change impacts on New Zealand agriculture, backed by scientific research and comprehensive reports.

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4. Planning and design

Artificial intelligence



Climate & Agriculture Gen AI System Connected Clear Export

How will pasture production be impacted by climate change across Selwyn District? 11:17 AM

Climate Change Impacts on Pasture Production in Selwyn District

Based on the climate projections and pasture production modeling for Selwyn District, several changes are expected in pasture production across the region under different climate change scenarios.

Projected Changes in Pasture Production

Under mid-century climate change scenarios, pasture production in Selwyn District is expected to experience the following changes:

- **Current baseline:** The mean pasture production is approximately 9,318 kg DM/ha (R5)
- **Under RCP2.6** (low emissions): Mean pasture production is projected to increase to around 12,517-13,587 kg DM/ha (R4)
- **Under RCP4.5** (intermediate emissions): Mean pasture production is projected to increase to approximately 12,819-13,000 kg DM/ha (R2)
- **Under RCP6.0** (intermediate-high emissions): Mean pasture production is projected to increase to around 12,921-14,253 kg DM/ha (R3)
- **Under RCP8.5** (high emissions): Mean pasture production is projected to increase to approximately 13,655-15,210 kg DM/ha (R1)

Spatial Variability

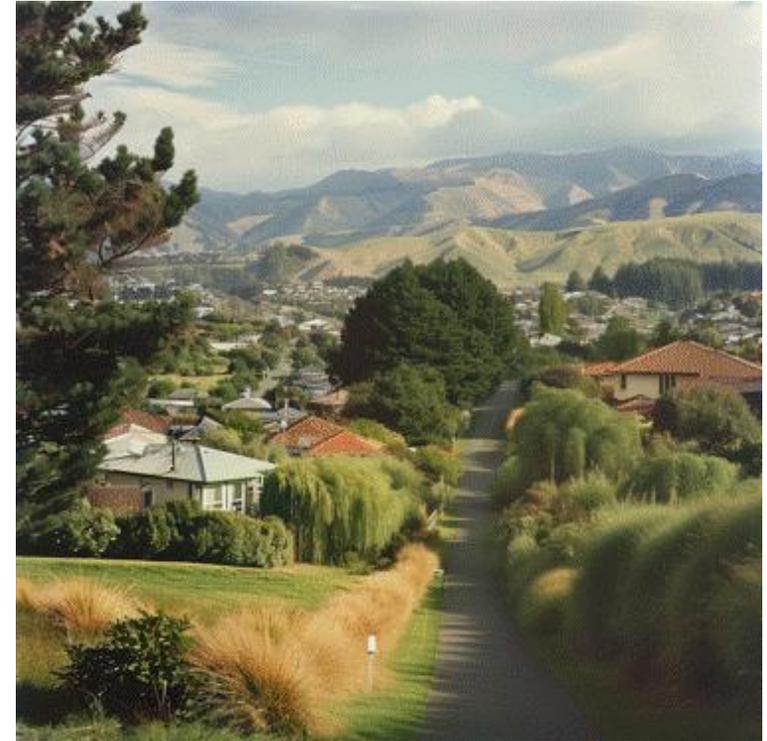
The impacts will not be uniform across the district:

- **Higher production areas:** Central and southern areas of Selwyn District are projected to maintain the highest pasture production values (exceeding 20,000 kg DM/ha in some locations), likely due to favorable conditions including better soil moisture retention and effective irrigation (R1, R2, R3, R4)
- **Lower production areas:** Northern and northwestern areas and around streams like Bull Creek, Mount Williams, and Kilmarnock Glacier (R3, R4)

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**Greater Christchurch
Partnership**

Te Tira Tū Tahī
One Group, Standing Together

Selwyn District Council,
Christchurch City Council, Kāinga
Ora, NZTA, Environment
Canterbury, Greater Christchurch
Partnership

4. Planning and design

Artificial intelligence



- Responsible and ethical applications of AI
- Risks of misinformation and other nefarious uses
- Energy and carbon costs

Ecosystem services for landscape planning and design



1. Ecosystem services are key to successful futures
2. To plan and design, we need to quantify ecosystem services
3. Simulation must play a bigger role in design
4. Science must connect to policy at national, regional, and local scales

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