Manaaki Whenua
Landcare Research

AI-powered tree mapping in urban, rural and forest environments

Jan Schindler

- Trees play key role in urban and natural ecosystems
- Carbon sequestration, climate regulation, reducing soil erosion, habitat for native and predator species, plantation, hydrology, …
- Need for mapping, modelling and managing individual trees in different environments

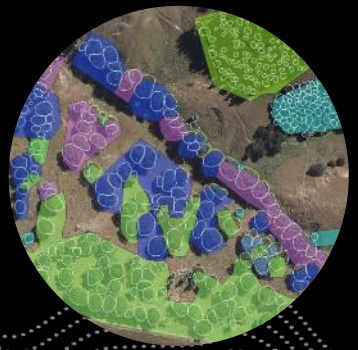
Outline

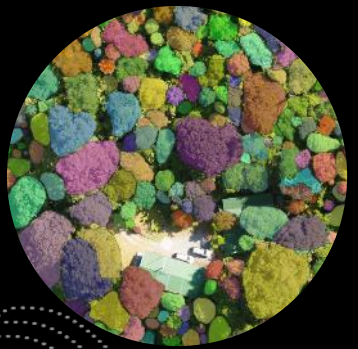
- LiDAR-based approach
- AI methods
- General workflow
- Case studies:

urban

rural

native forests





Tree crown segmentation at MWLR

Developed algorithm to segment individual crowns from aerial LiDAR

Advanced Remote Sensing of Aotearoa (ARSA)

Improved region-growing algorithm from canopy height models

Applications:

- region-wide analyses
- species detection
- Landslide risk

Tree crown segmentation at MWLR

Developed algorithm to segment individual crowns from aerial LiDAR

Advanced Remote Sensing of Aotearoa (ARSA)

Improved region-growing algorithm from canopy height models

Applications:

- region-wide analyses
- species detection
- Landslide risk

Tree crown segmentation at MWLR

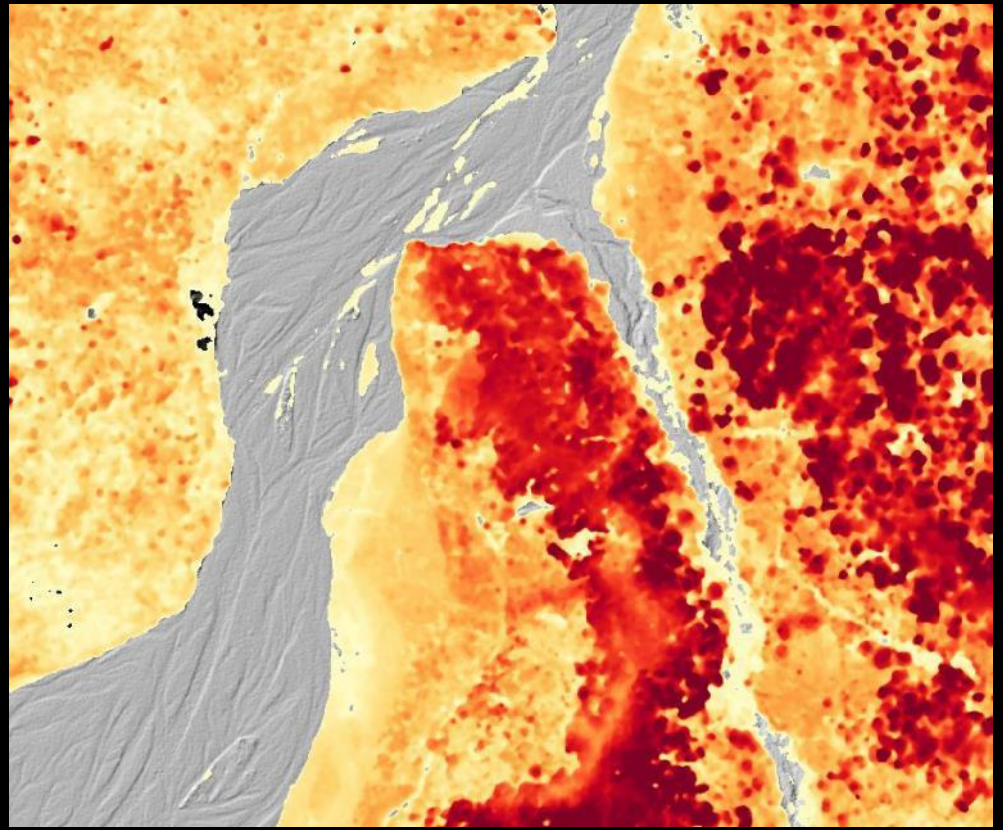
Developed algorithm to segment individual crowns from aerial LiDAR

Advanced Remote Sensing of Aotearoa (ARSA)

Improved region-growing algorithm from canopy height models

Applications:

- region-wide analyses
- species detection
- Landslide risk



Tree crown segmentation at MWLR

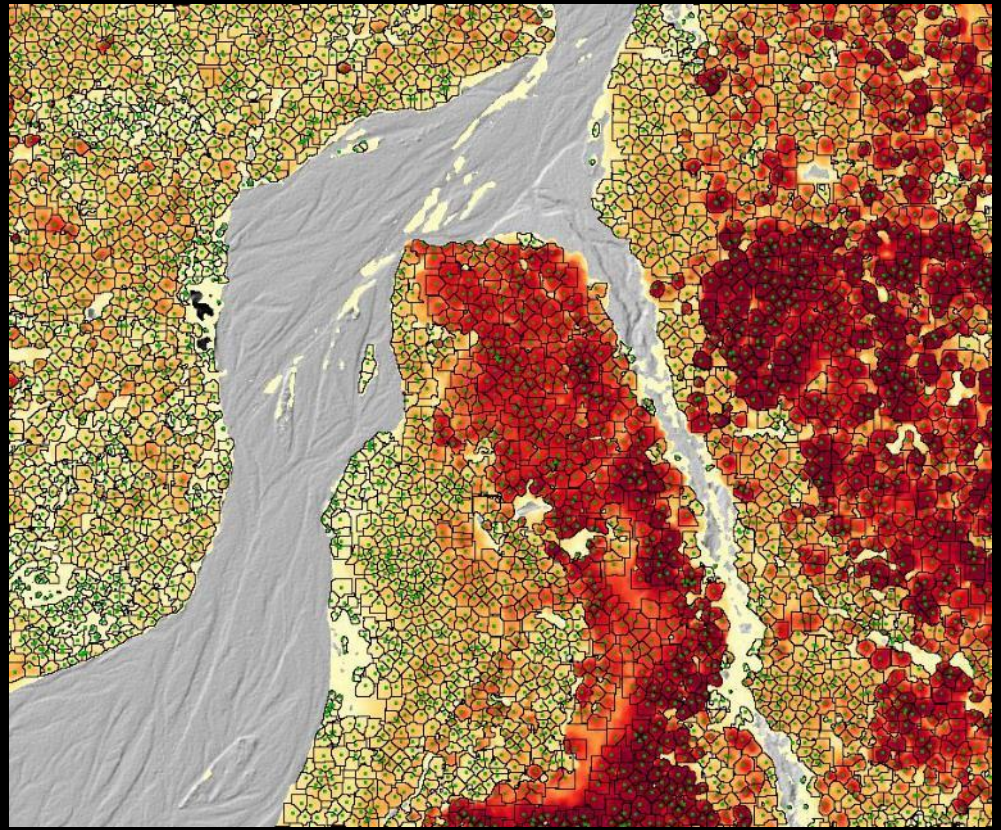
Developed algorithm to segment individual crowns from aerial LiDAR

Advanced Remote Sensing of Aotearoa (ARSA)

Improved region-growing algorithm from canopy height models

Applications:

- region-wide analyses
- species detection
- Landslide risk



Tree crown segmentation at MWLR

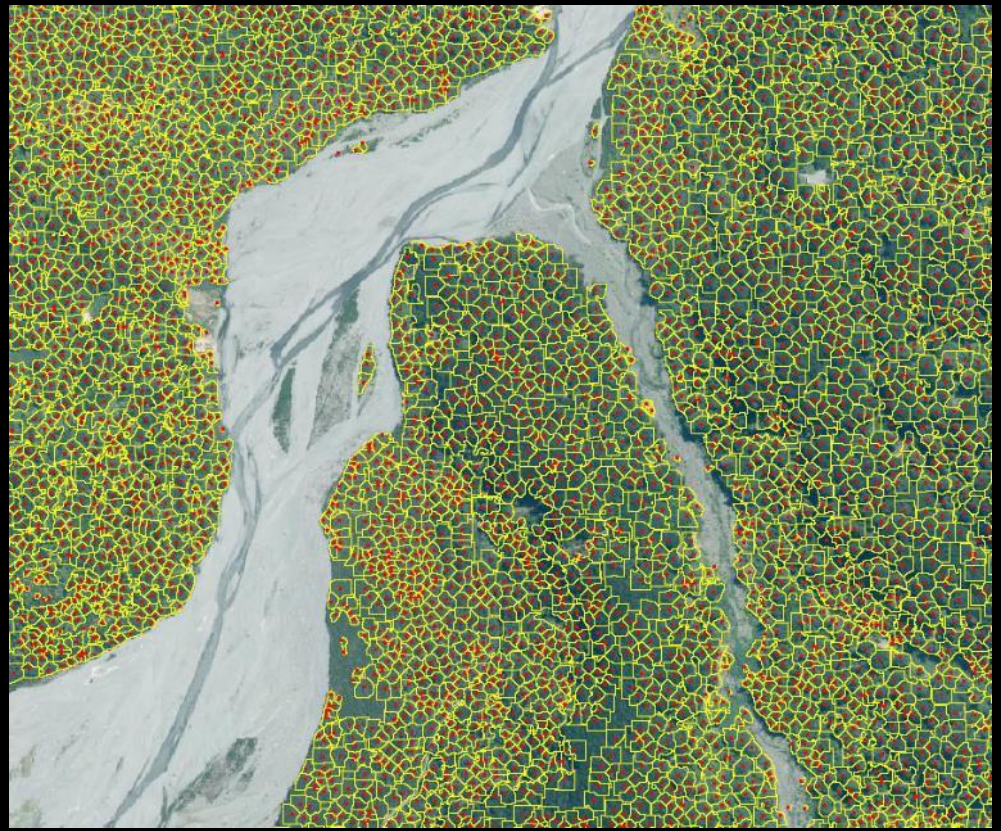
Developed algorithm to segment individual crowns from aerial LiDAR

Advanced Remote Sensing of Aotearoa (ARSA)

Improved region-growing algorithm from canopy height models

Applications:

- region-wide analyses
- species detection
- Landslide risk



Tree crown segmentation at MWLR

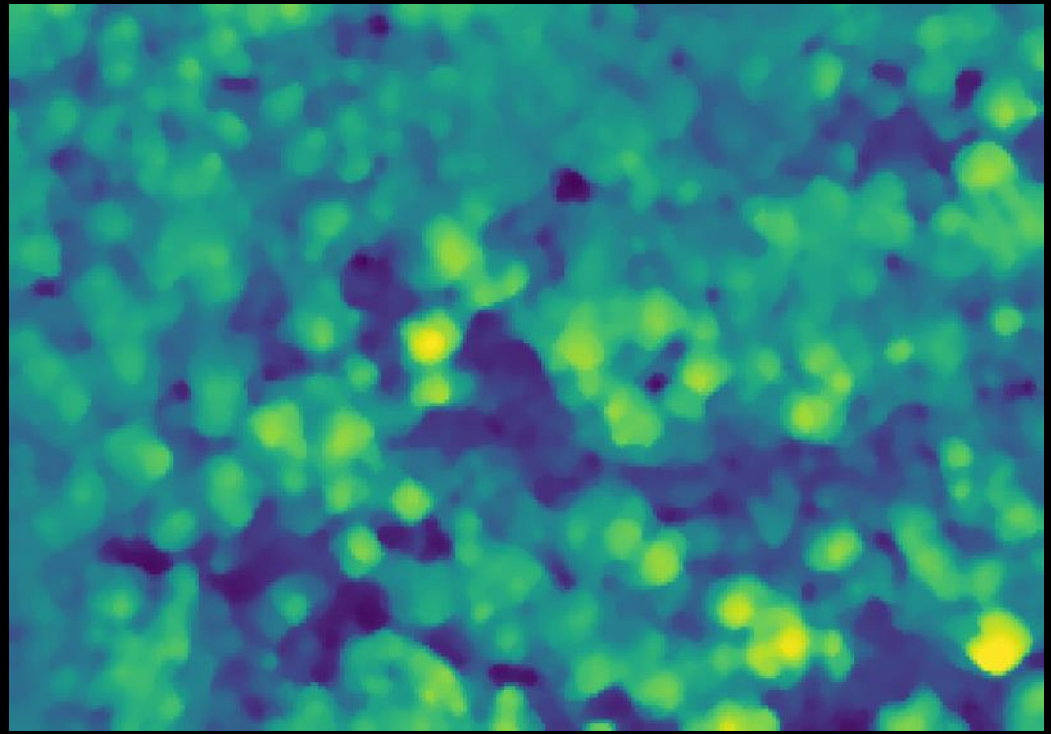
Developed algorithm to segment individual crowns from aerial LiDAR

Advanced Remote Sensing of Aotearoa (ARSA)

Improved region-growing algorithm from canopy height models

Applications:

- region-wide analyses
- species detection
- Landslide risk



Tree crown segmentation at MWLR

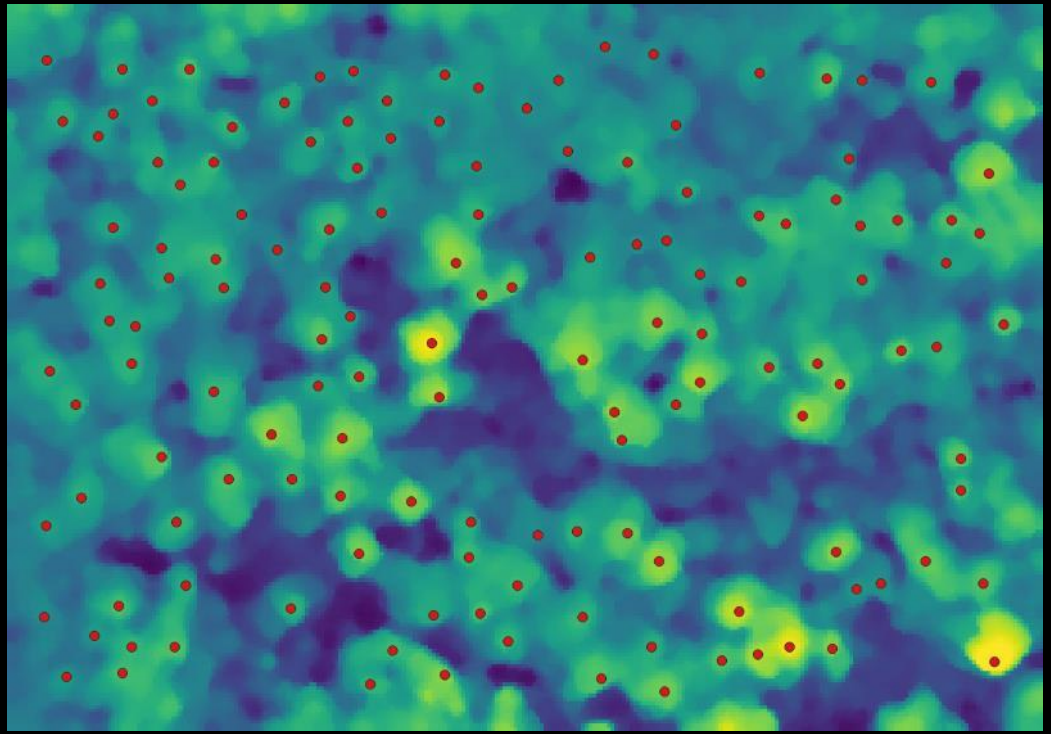
Developed algorithm to segment individual crowns from aerial LiDAR

Advanced Remote Sensing of Aotearoa (ARSA)

Improved region-growing algorithm from canopy height models

Applications:

- region-wide analyses
- species detection
- Landslide risk



Tree crown segmentation at MWLR

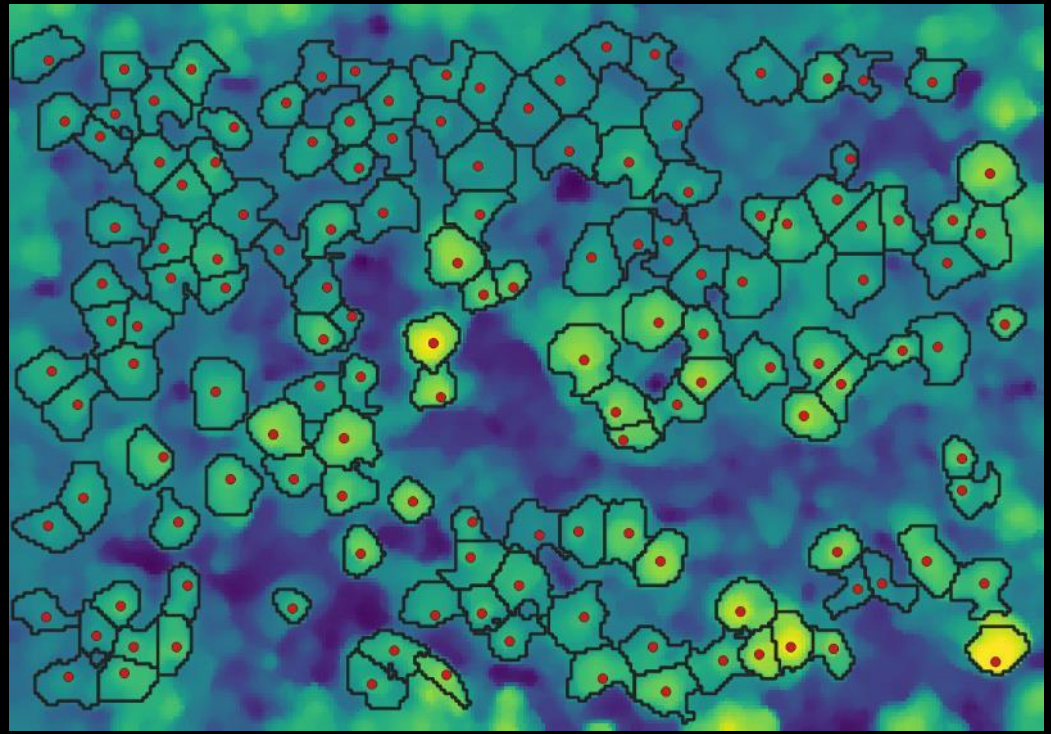
Developed algorithm to segment individual crowns from aerial LiDAR

Advanced Remote Sensing of Aotearoa (ARSA)

Improved region-growing algorithm from canopy height models

Applications:

- region-wide analyses
- species detection
- Landslide risk



Tree crown segmentation at MWLR

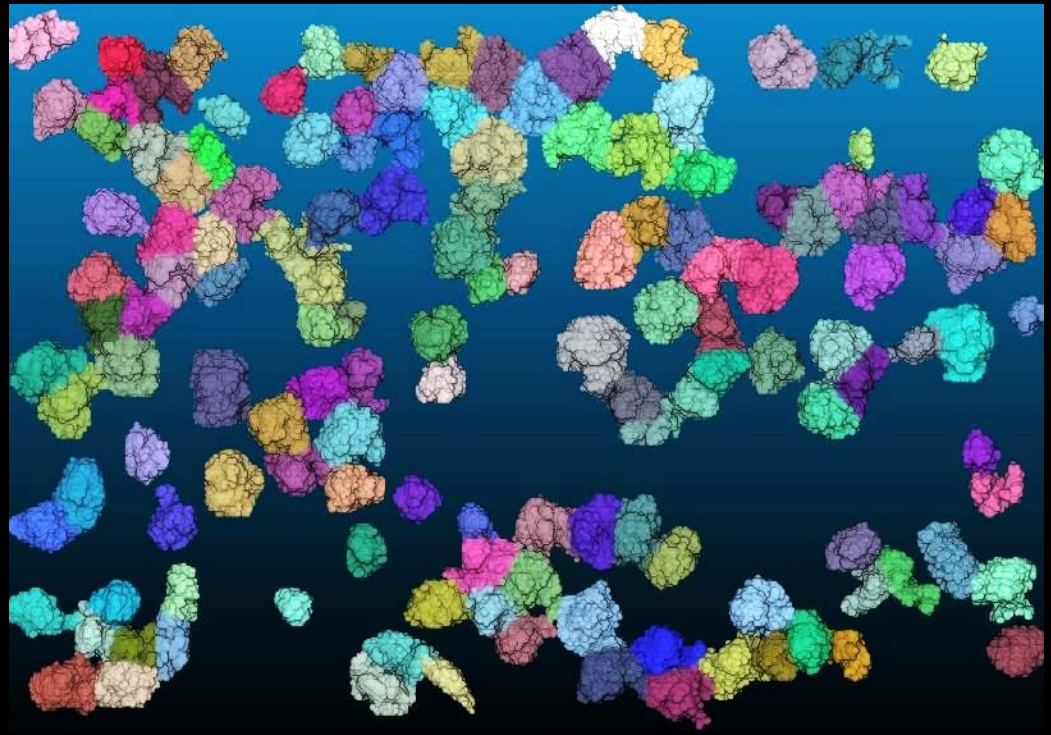
Developed algorithm to segment individual crowns from aerial LiDAR

Advanced Remote Sensing of Aotearoa (ARSA)

Improved region-growing algorithm from canopy height models

Applications:

- region-wide analyses
- species detection
- Landslide risk



Tree crown segmentation at MWLR

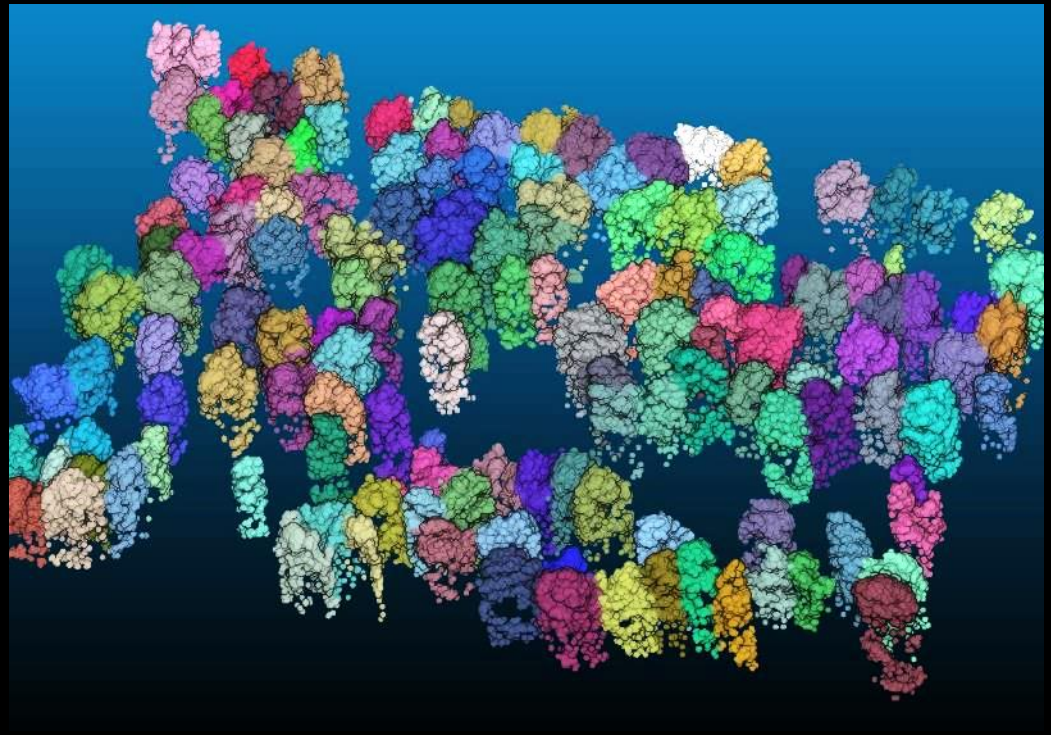
Developed algorithm to segment individual crowns from aerial LiDAR

Advanced Remote Sensing of Aotearoa (ARSA)

Improved region-growing algorithm from canopy height models

Applications:

- region-wide analyses
- species detection
- Landslide risk



forests

MDPI

Article

LiDAR-Based Regional Inventory of Tall Trees—Wellington, New Zealand

Jan Zörner [1,*], John R. Dymond [2], James D. Shepherd [2], Susan K. Wiser [1] and Ben Jolly [2]

[1] Landcare Research, Lincoln 7608, New Zealand; wisers@landcareresearch.co.nz
[2] Landcare Research, Palmerston North 4410, New Zealand; dymondj@landcareresearch.co.nz (J.R.D.); shepherdj@landcareresearch.co.nz (J.D.S.); jollyb@landcareresearch.co.nz (B.J.)
* Correspondence: zoernerj@landcareresearch.co.nz; Tel.: +64-3-321-9720

Received: 8 October 2018; Accepted: 10 November 2018; Published: 13 November 2018

check for updates

Abstract: Indigenous forests cover 23.9% of New Zealand's land area and provide highly valued ecosystem services, including climate regulation, habitat for native biota, regulation of soil erosion and recreation. Despite their importance, information on the number of tall trees and the tree height distribution across different forest classes is scarce. We present the first region-wide spatial inventory of tall trees (>30 m) based on airborne LiDAR (Light Detection and Ranging) measurements in New Zealand—covering the Greater Wellington region. This region has 159,000 ha of indigenous forest, primarily on steep mountainous land. We implement a high-performance tree mapping algorithm that uses local maxima in a canopy height model (CHM) as initial tree locations and accurately identifies the tree top positions by combining a raster-based tree crown delineation approach with information from the digital surface and terrain models. Our algorithm includes a check and correction for over-estimated heights of trees on very steep terrain such as on cliff edges. The number of tall trees (>30 m) occurring in indigenous forest in the Wellington Region is estimated to be 286,041 (±1%) and the number of giant trees (>40 m tall) is estimated to be 7340 (±1%). Stereo-analysis of aerial photographs was used to determine the accuracy of the automated tree mapping. The giant trees are mainly in the beech-broadleaved-podocarp and broadleaved-podocarp forests, with density being 0.04 and 0.12 (trees per hectare) respectively. The inventory of tall trees in the Wellington Region established here improves the characterization of indigenous forests for management and provides a useful baseline for long-term monitoring of forest conditions. Our tree top detection scheme provides a simple and fast method to accurately map overstory trees in flat as well as mountainous areas and can be directly applied to improve existing and build new tree inventories in regions where LiDAR data is available.

Keywords: forest inventory; LiDAR; tall trees; overstory trees; tree mapping; crown delineation

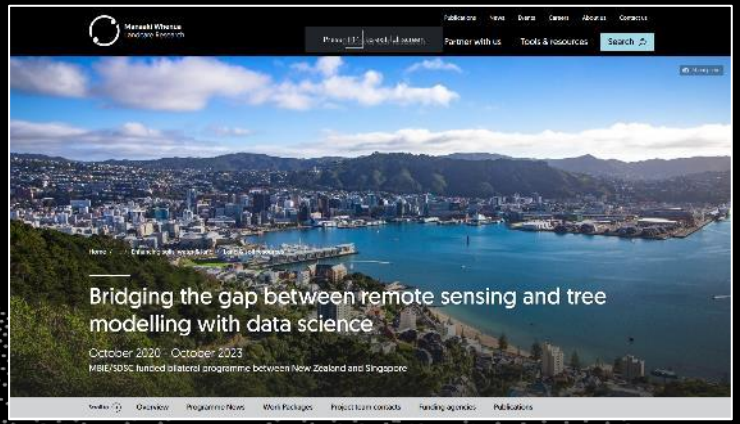
Indigenous Forest

Forest Alliance Group	Area (ha)	> 30m	>35m	>40m	>45m
Beech	37402	47646	4911	410	44
Beech-broadleaved	7946	4911	598	108	9
Beech-broadleaved podocarp	81155	176518	28903	3202	293
Broadleaved-podocarp	17341	33493	11268	2103	226
Podocarp	71	129	4	0	0
Broadleaved	5172	3689	1357	302	43
Unspecified indigenous	9956	19202	5944	1210	170
Subalpine shrubland	3841	453	44	5	0
Total	*162884*	*286041*	*53029*	*7340*	*785*

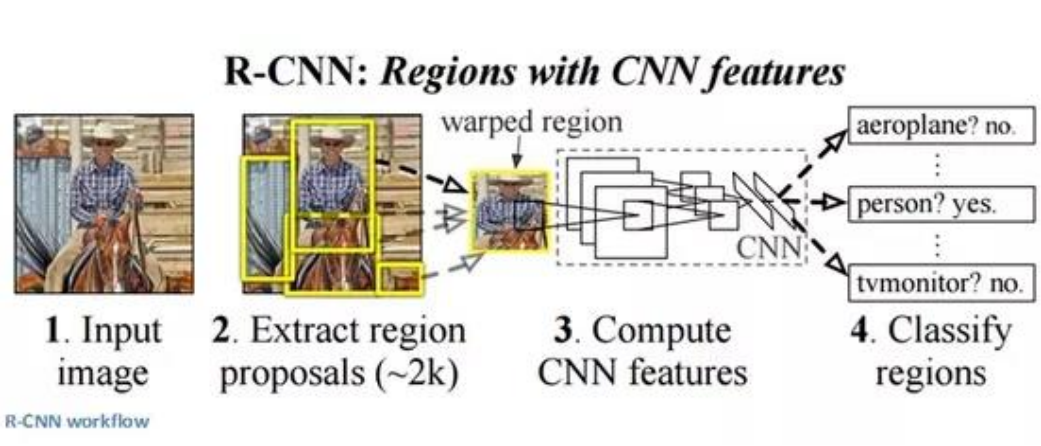
AI-based tree crown mapping

- High-resolution RGB aerial imagery
- Finer detail of crown polygons and better detection rate
- Can be applied everywhere in NZ, no LiDAR needed
- NZ-Singapore Data Science Programme on AI tree research (MBIE Catalyst funded)

www.landcareresearch.co.nz/nzsg-datascience

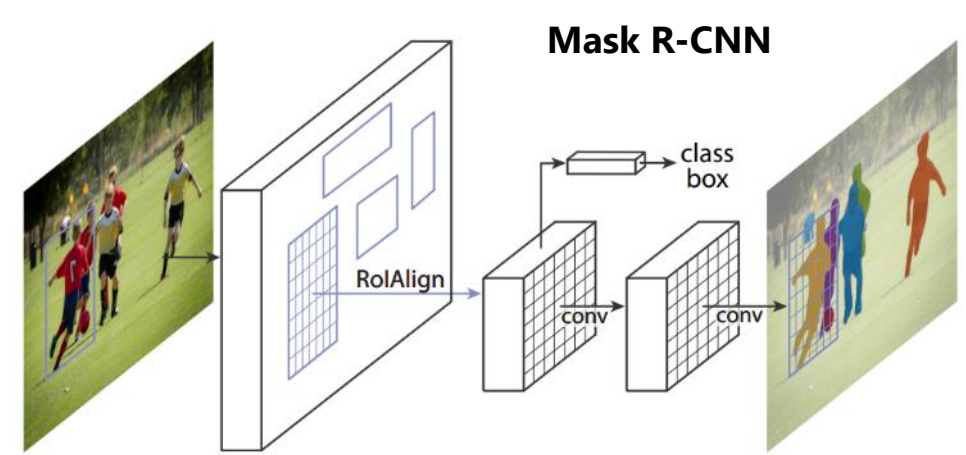


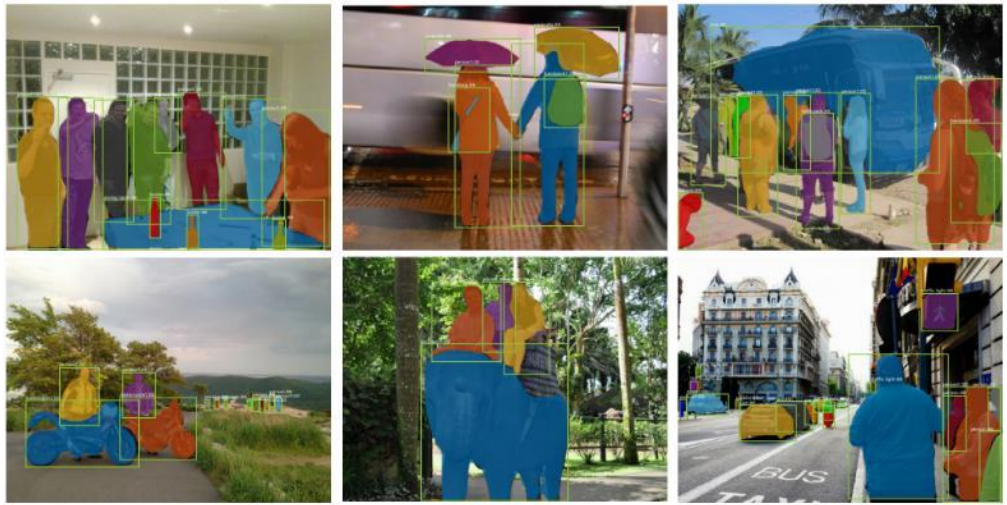
AI methods for object detection + instance segmentation



Girshick, R., Donahue, J., Darrell, T., & Malik, J. (2014). Rich feature hierarchies for accurate object detection and semantic segmentation. In *Proceedings of the IEEE conference on computer vision and pattern recognition* (pp. 580-587).

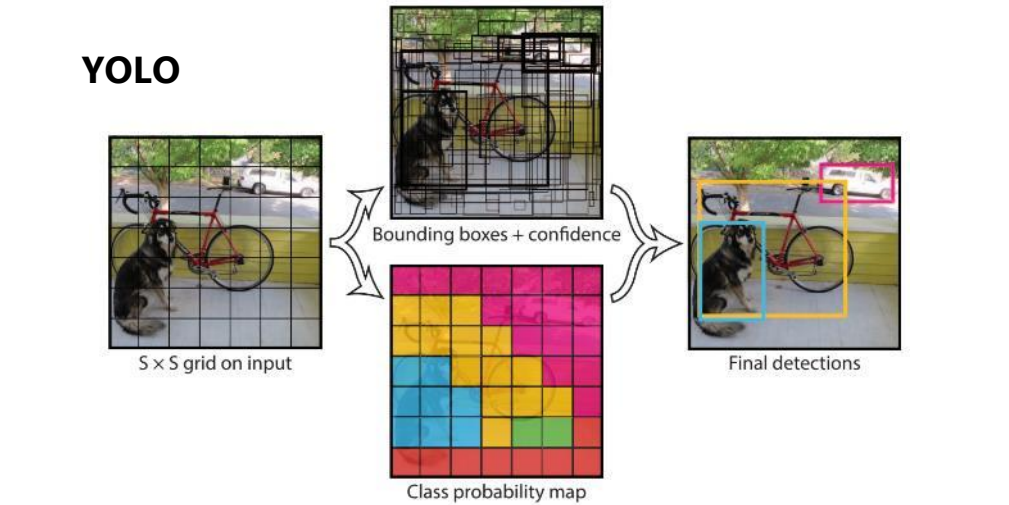
AI methods for object detection + instance segmentation

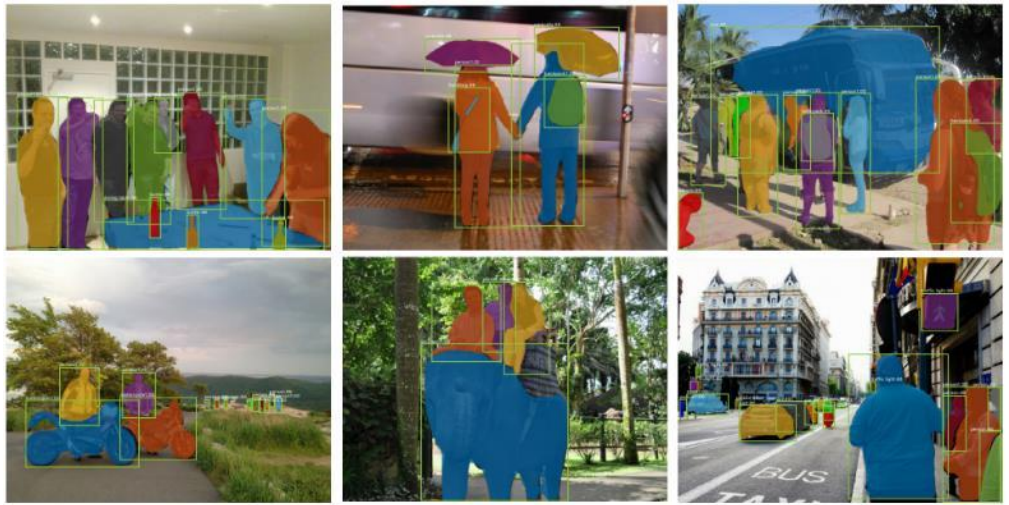




He, K., Gkioxari, G., Dollár, P., & Girshick, R. (2017). Mask r-cnn. In *Proceedings of the IEEE international conference on computer vision* (pp. 2961-2969).

AI methods for object detection + instance segmentation





Redmon, J., Divvala, S., Girshick, R., & Farhadi, A. (2016). You only look once: Unified, real-time object detection. In *Proceedings of the IEEE conference on computer vision and pattern recognition* (pp. 779-788).

He, K., Gkioxari, G., Dollár, P., & Girshick, R. (2017). Mask r-cnn. In *Proceedings of the IEEE international conference on computer vision* (pp. 2961-2969).

Zhao, H., Morgenroth, J., Pearse, G., & Schindler, J. (2023). A Systematic Review of Individual Tree Crown Detection and Delineation with Convolutional Neural Networks (CNN). *Current Forestry Reports*, 1-22.

Fu, W., Xue, B., Zhang, M. and Schindler, J. (2023) February. Evolving U-Nets Using Genetic Programming for Tree Crown Segmentation. In Image and Vision Computing: 37th International Conference, IVCNZ 2022, Auckland, New Zealand, November 24–25, 2022, Revised Selected Papers (pp. 188-201). Cham: Springer Nature Switzerland.

Xu, B., Bi, Y., Xue, B., Schindler, J., Martin, B. and Zhang, M., (2022) December. Automatically Designing U-Nets Using A Genetic Algorithm for Tree Image Segmentation. In 2022 IEEE Symposium Series on Computational Intelligence (SSCI) (pp. 626-633). IEEE.

A Systematic Review of Individual Tree Crown Detection and Delineation with Convolutional Neural Networks (CNN)

Haotian Zhao, Justin Morgenroth, Grant Pearse & Jan Schindler

Current Forestry Reports (2023) | Cite this article

Abstract

Purpose of Review

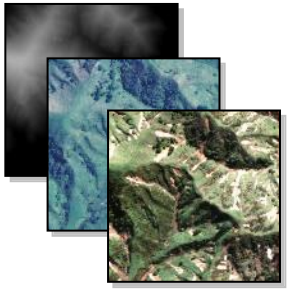
Crown detection and measurement at the individual tree level provide detailed information for accurate forest management. To efficiently acquire such information, approaches to conduct individual tree detection and crown delineation (ITDCD) using remotely sensed data have been proposed. In recent years, deep learning, specifically convolutional neural networks

https://link.springer.com/article/10.1007/s40725-023-00184-3

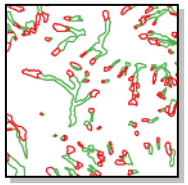
Deep learning workflow

for segmentation of remote sensing imagery

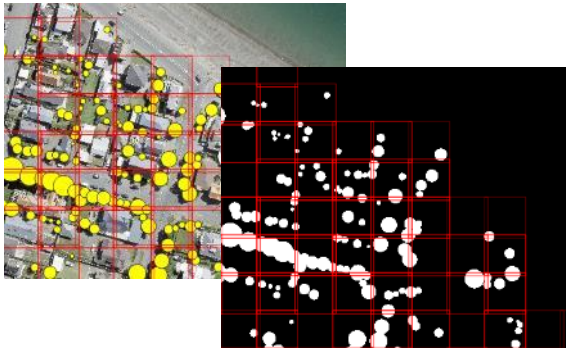
Image stack



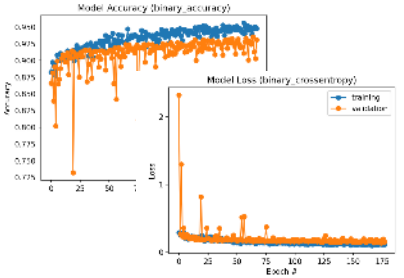
Label file



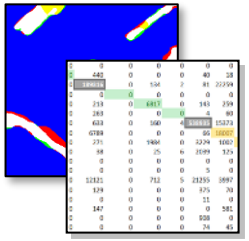
Rasterization & tiling into one HDF5 file



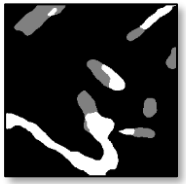
Training



Accuracy assessment

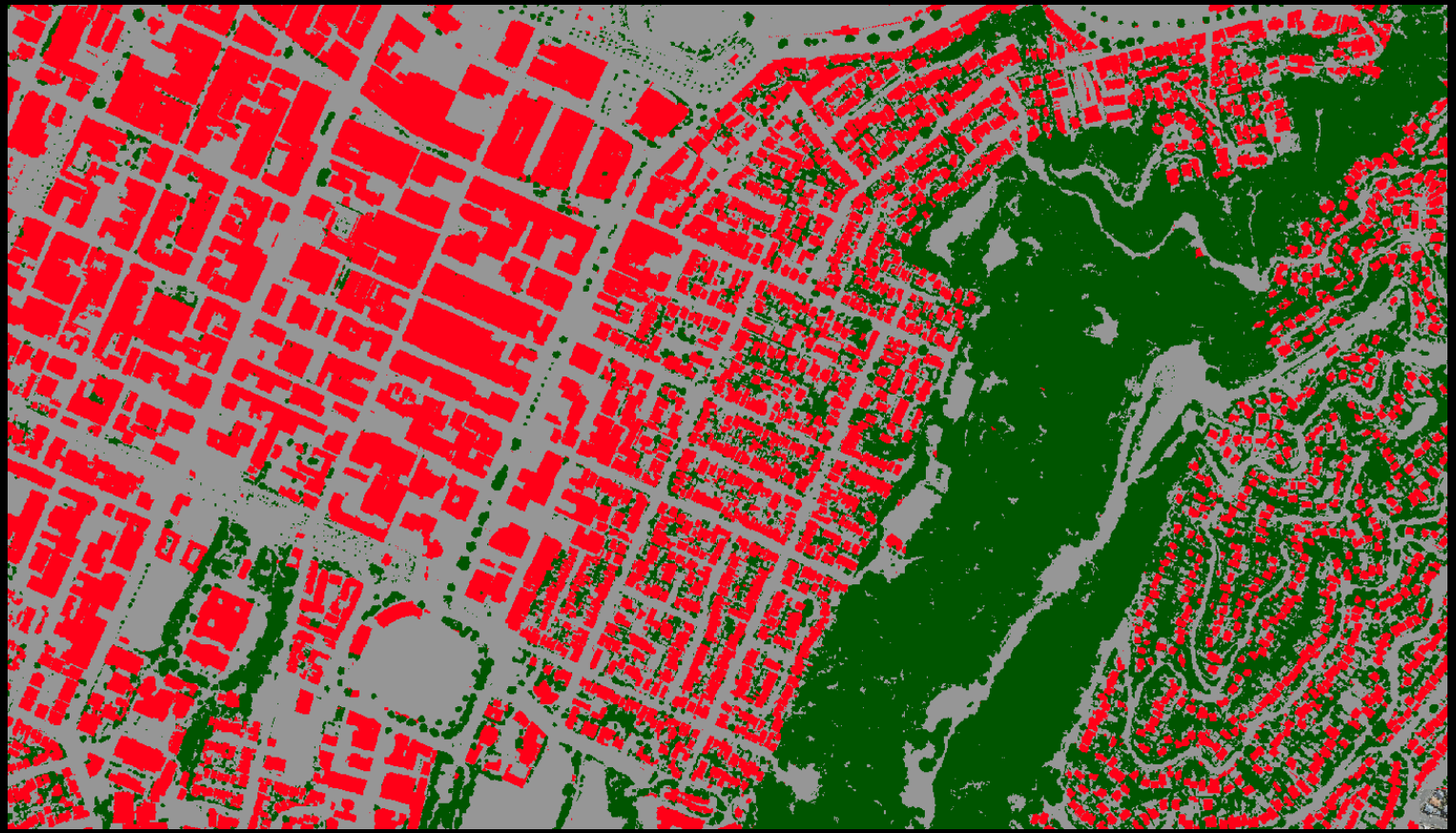


Prediction



Tree canopy segmentation from RGB imagery

Tree canopy segmentation from RGB imagery



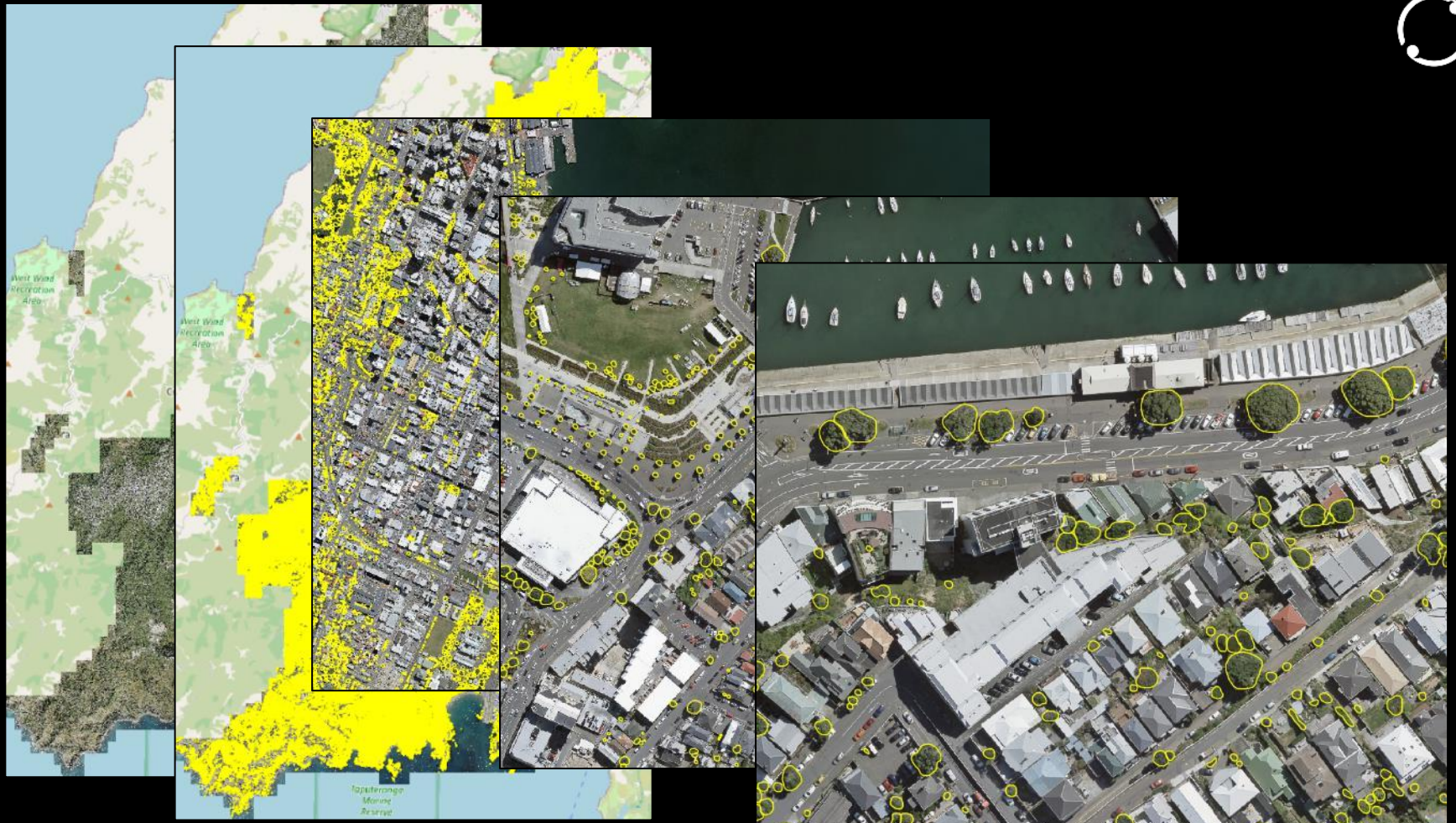
Tree object detection in RGB aerial imagery at 10cm

Tree object detection high-quality Mask R-CNN polygons (slow, large file)

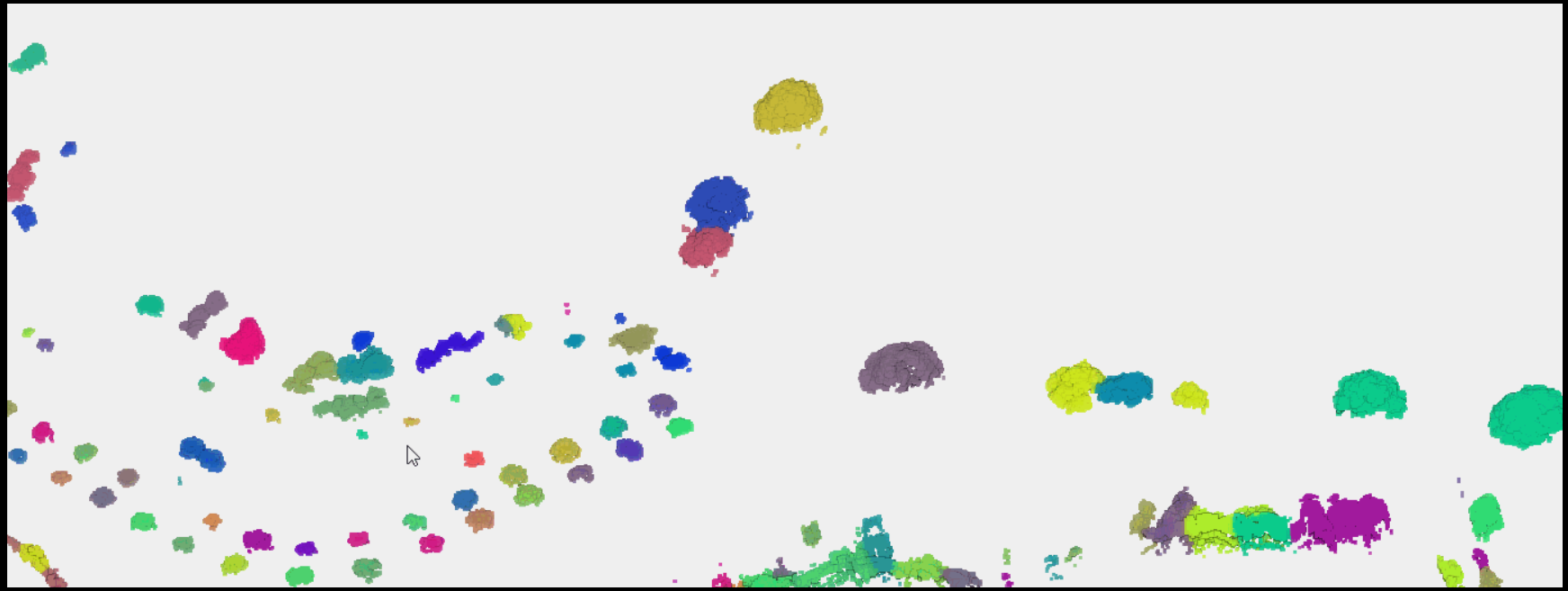
Tree object detection bounding boxes from Mask R-CNN and YOLO (fast, small file)

Tree object detection circles from Mask R-CNN and YOLO (fast, large file)

Tree object detection circles from Mask R-CNN and YOLO (fast, very small file)


West Wind Recreation Area
West Wind Recreation Area
Taputerango Marine Reserve

3D Tree Instance Segmentation using Mask R-CNN crown predictions



Interactive tree map of Wellington City

wtree.landcareresearch.co.nz

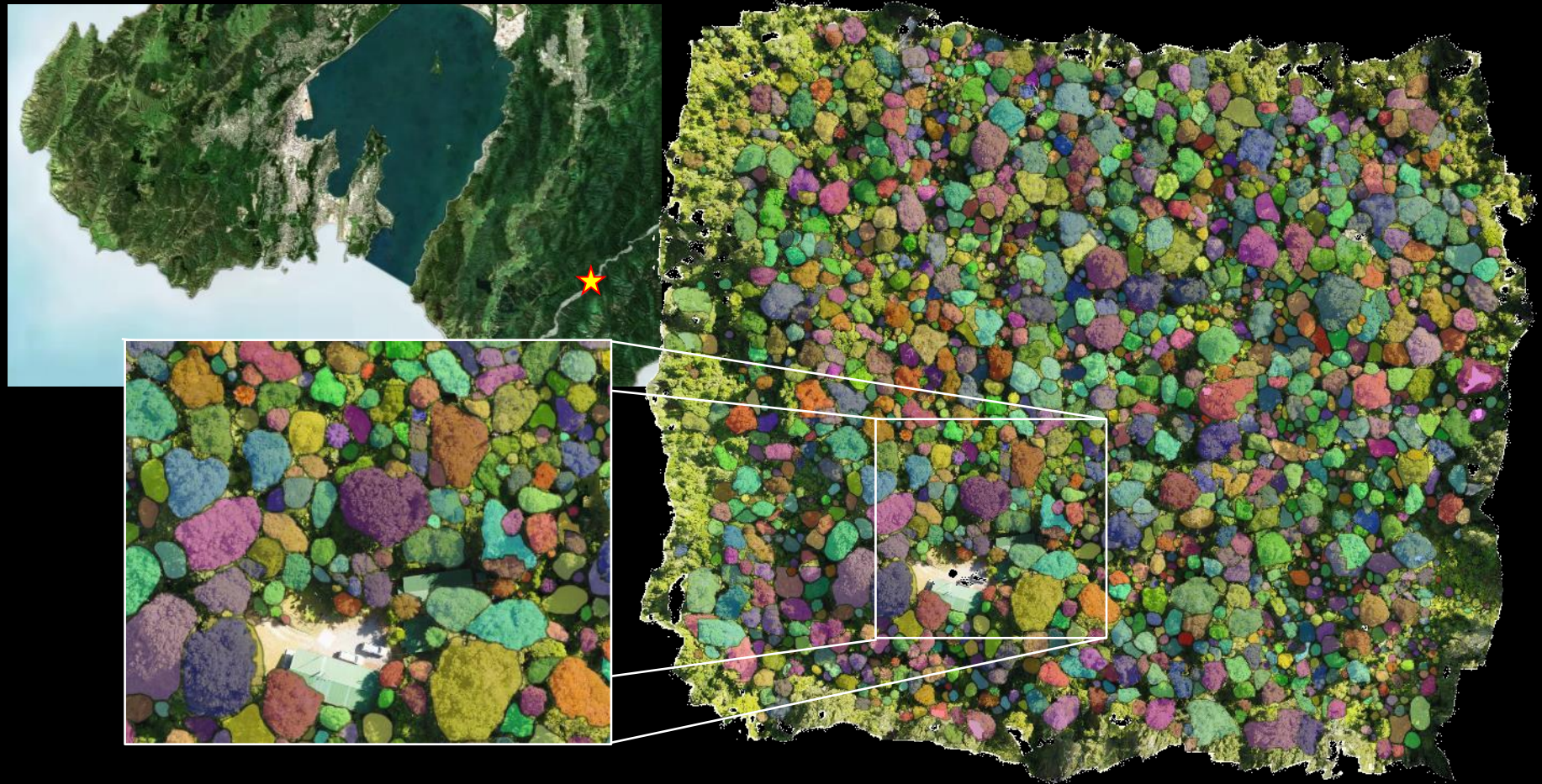
Native forest case study: tree segmentation from RGB aerial imagery at 30 cm

Native forest case study: tree segmentation from RGB aerial imagery at 30 cm

Native forest case study: tree segmentation from RGB aerial imagery at 30 cm

Native forest case study: tree segmentation from RGB drone imagery at 2 cm

Native forest case study: tree segmentation from RGB drone imagery at 2 cm

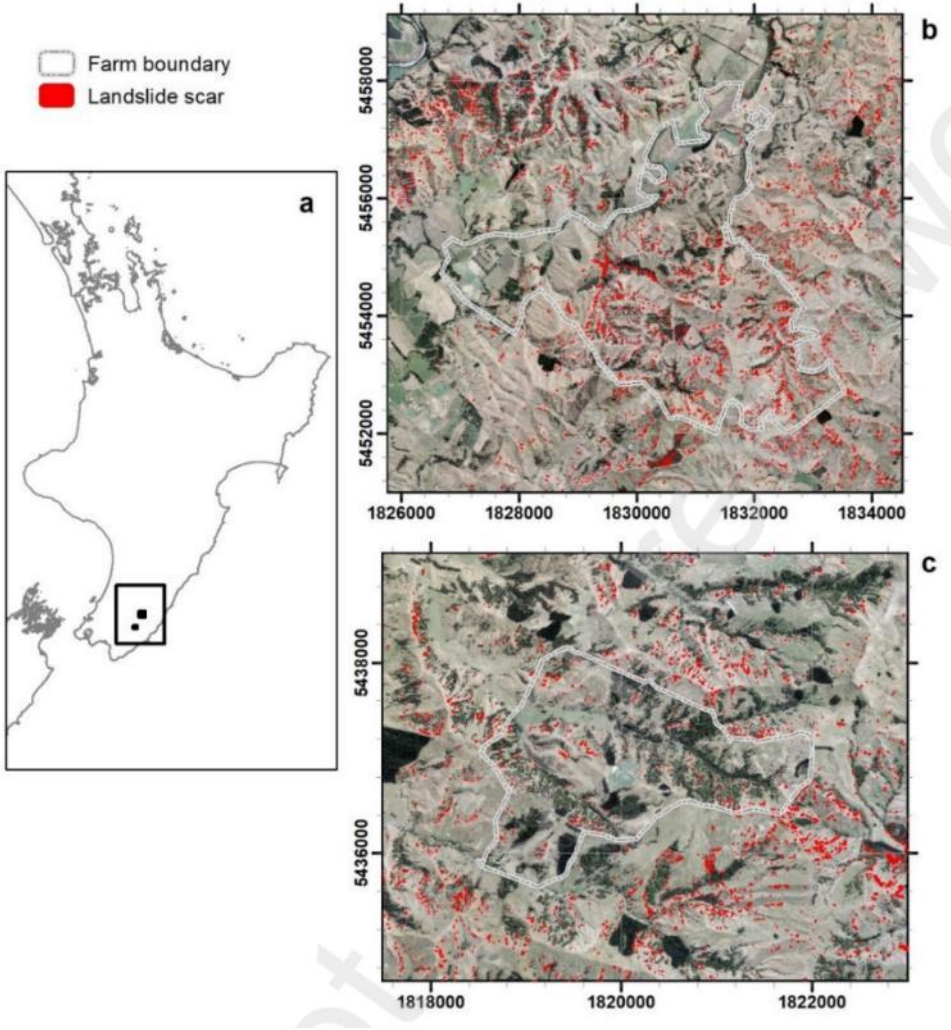


Tree species mapping in pastoral hill-country

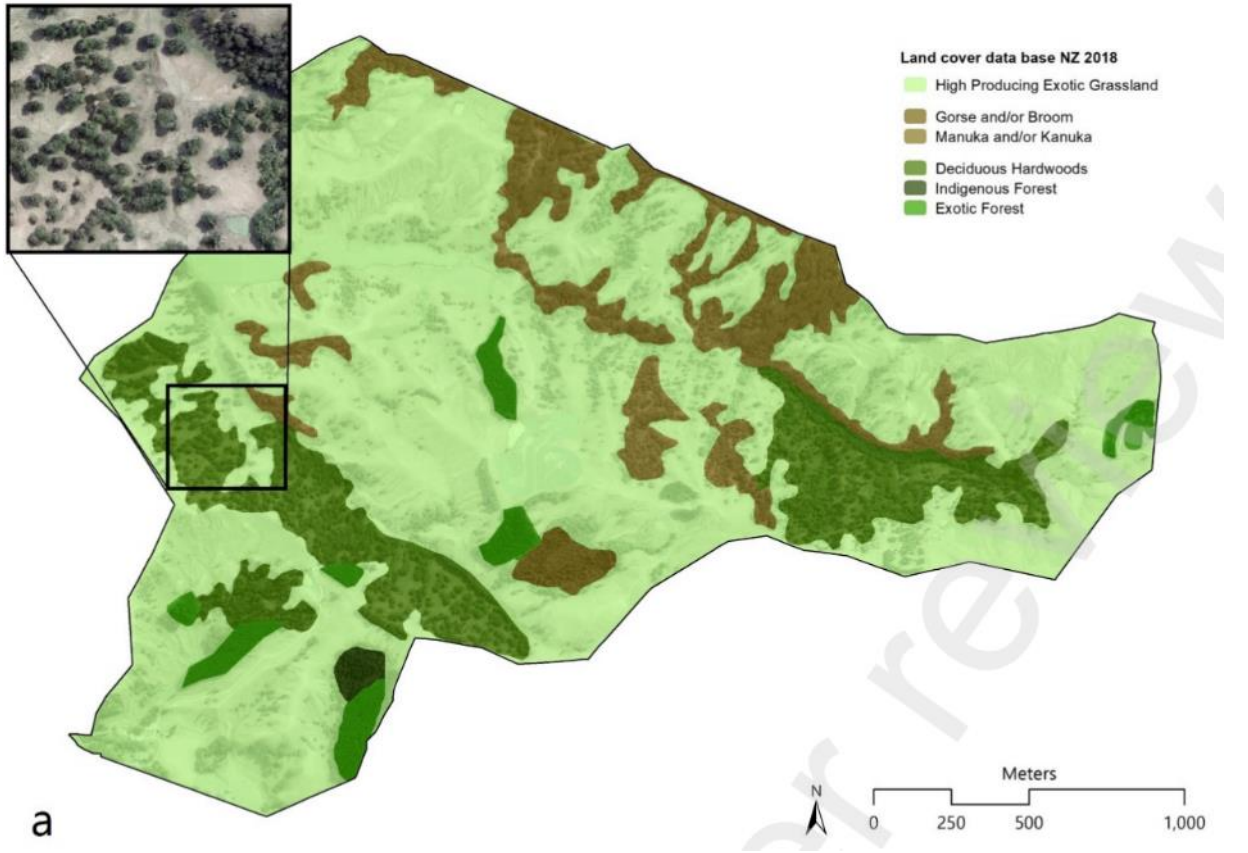
Smarter Targeting for Erosion Control (STEC)
https://www.landcareresearch.co.nz/discover-our-research/land/erosion-and-sediment/smarter-targeting-of-erosion-control/

https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4347971

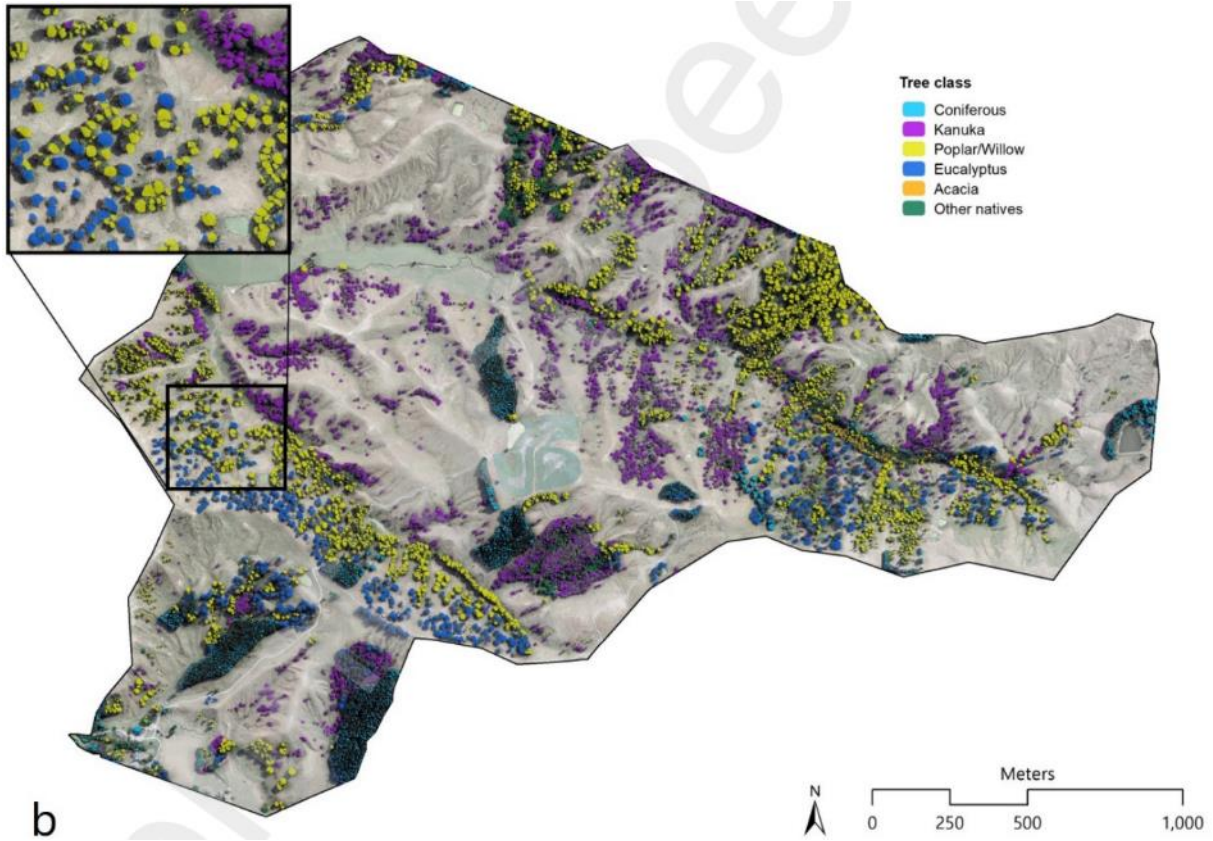
Tree species mapping in pastoral hill-country



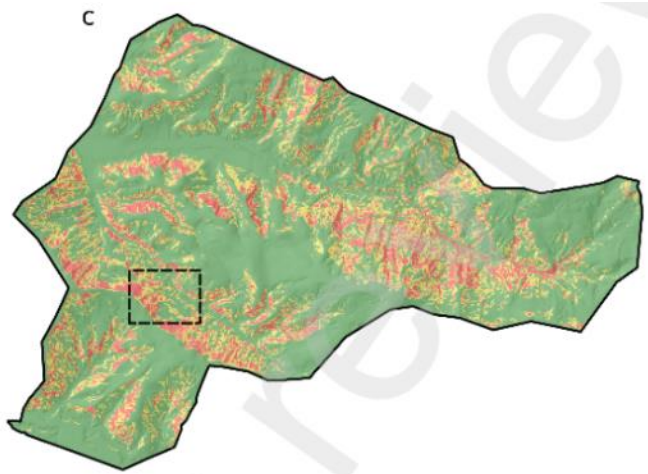
Tree species mapping in pastoral hill-country

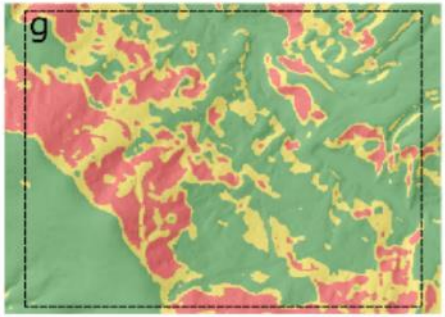


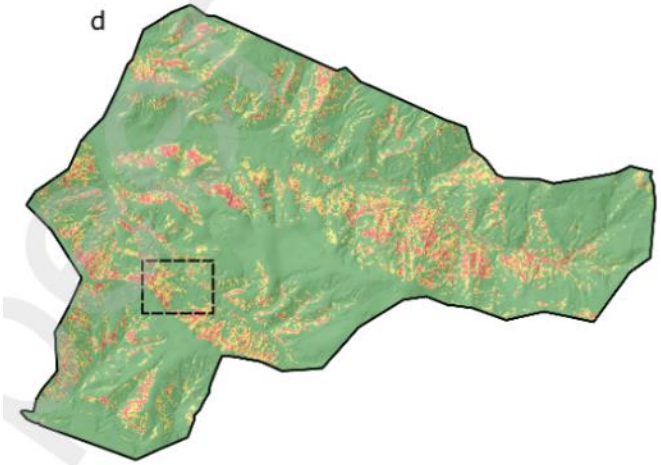
Tree species mapping in pastoral hill-country

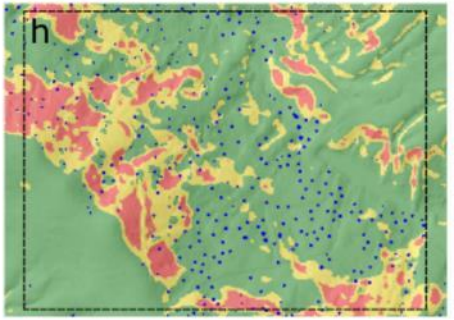


Tree species mapping in pastoral hill-country









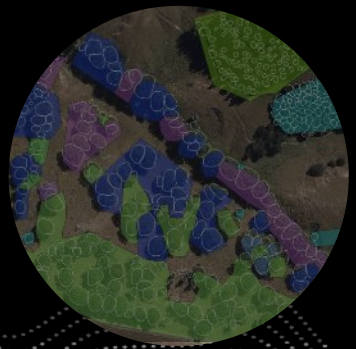
What's next?

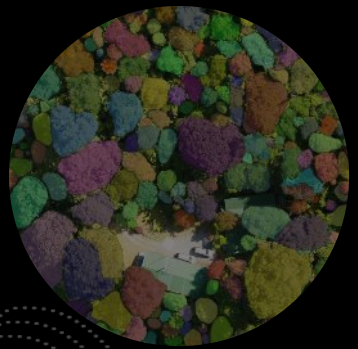
- Species Mapping
- Combining of data sets
- University collaborations
- 3D Point Clouds

urban

rural

native forests





Manaaki Whenua
Landcare Research

Thank you

schindlerj@landcareresearch.co.nz