Mapping winter forage crops from time series satellite imagery: supporting decision makers and policy planners.

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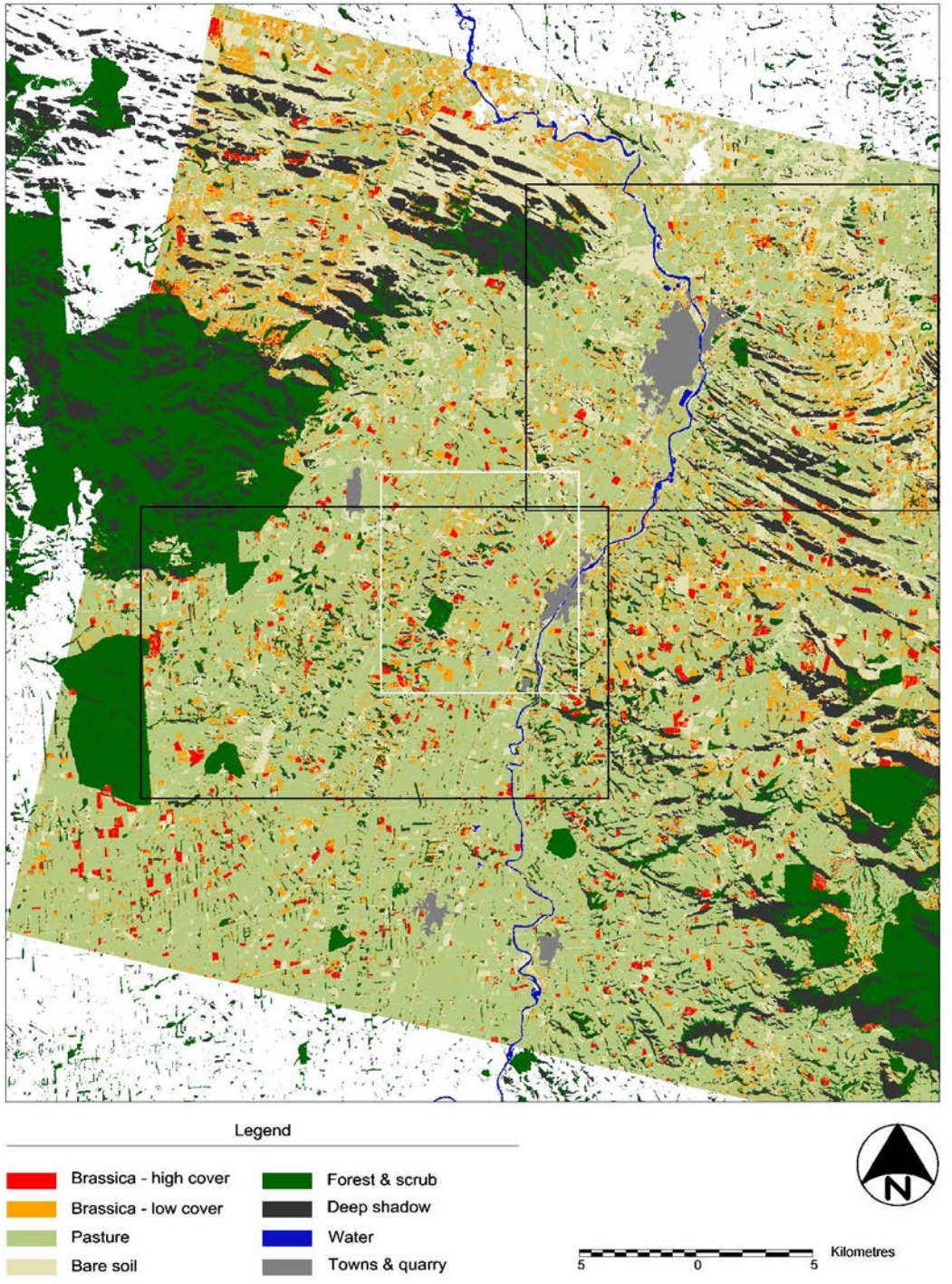
Manaaki Whenua
Landcare Research


Kale
Rape
Swedes and turnips
Fodder beet
Cereals – oats, barley
Intensively grazed pastures

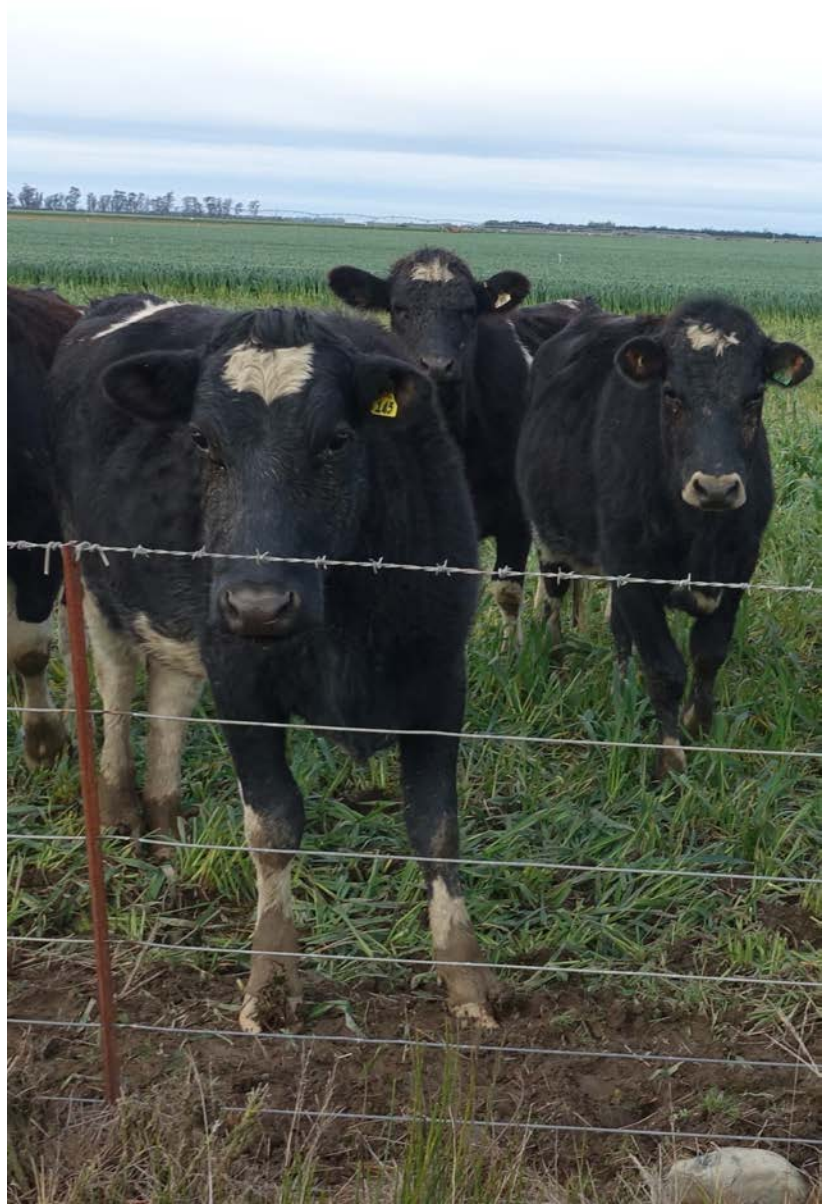
Initial trials in Southland to develop and test methodology options

- Test site around Gore-Mataura
- 3 SPOT sub-images – May, July, September (augmented by Landsat -7 & -8) in winter 2013
- Investigated single-date vs. multi-date classification, and date-stamping of grazing times
- Good separation of brassicas and beets from pastures
- Sun elevation angles down to ~ 11 degrees challenged radiometric calibration



Winter forage maps produced

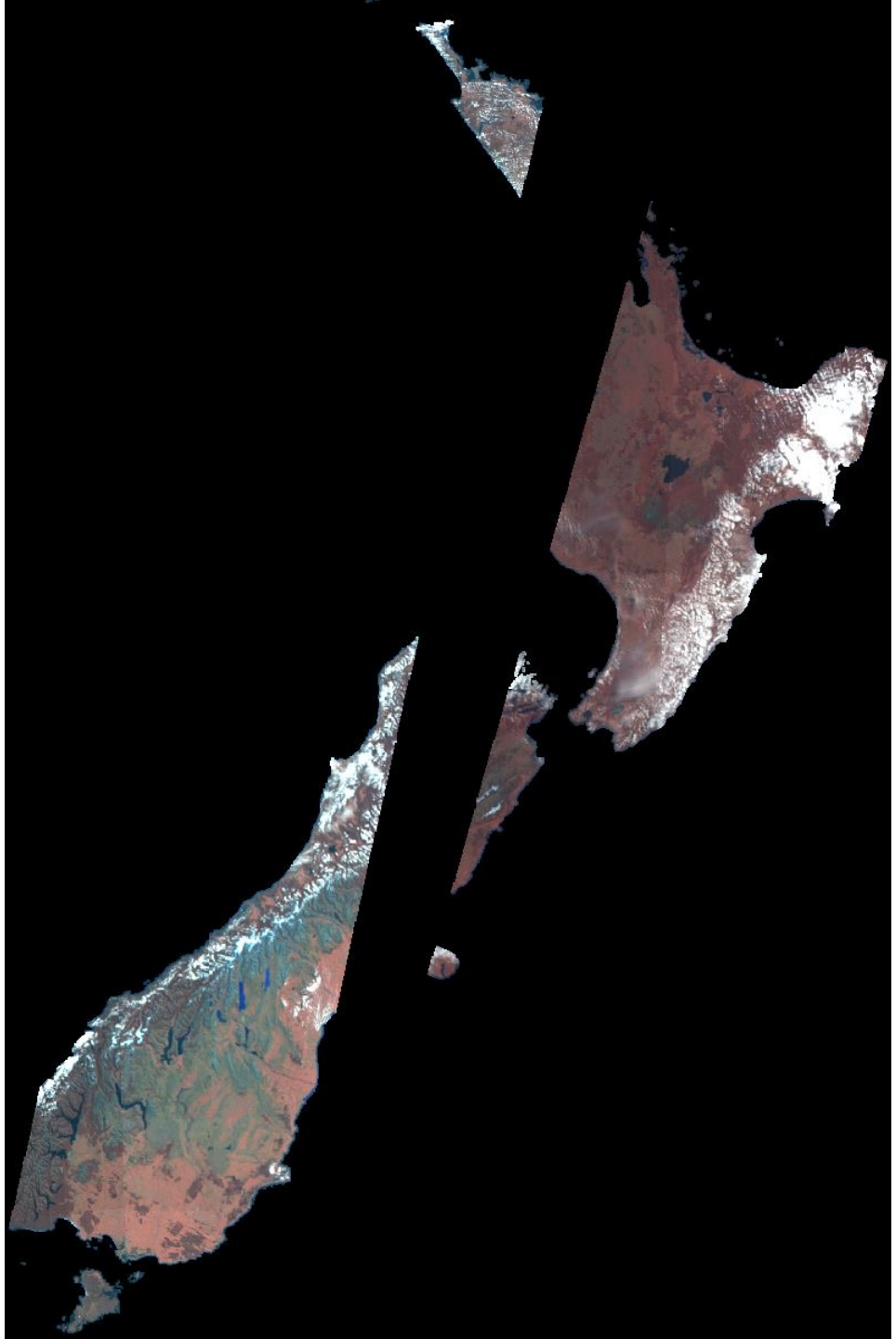
- Southland 2014 and 2017.
- Canterbury 2016 and 2020
- Hawkes Bay 2018 plus “fast” WF map 2021
- All hill (over 7 degrees average slope) country 2018
- All hill country bare ground in the hill country agricultural land 2018.
- All New Zealand agricultural land 2021 & 2022 (in progress)

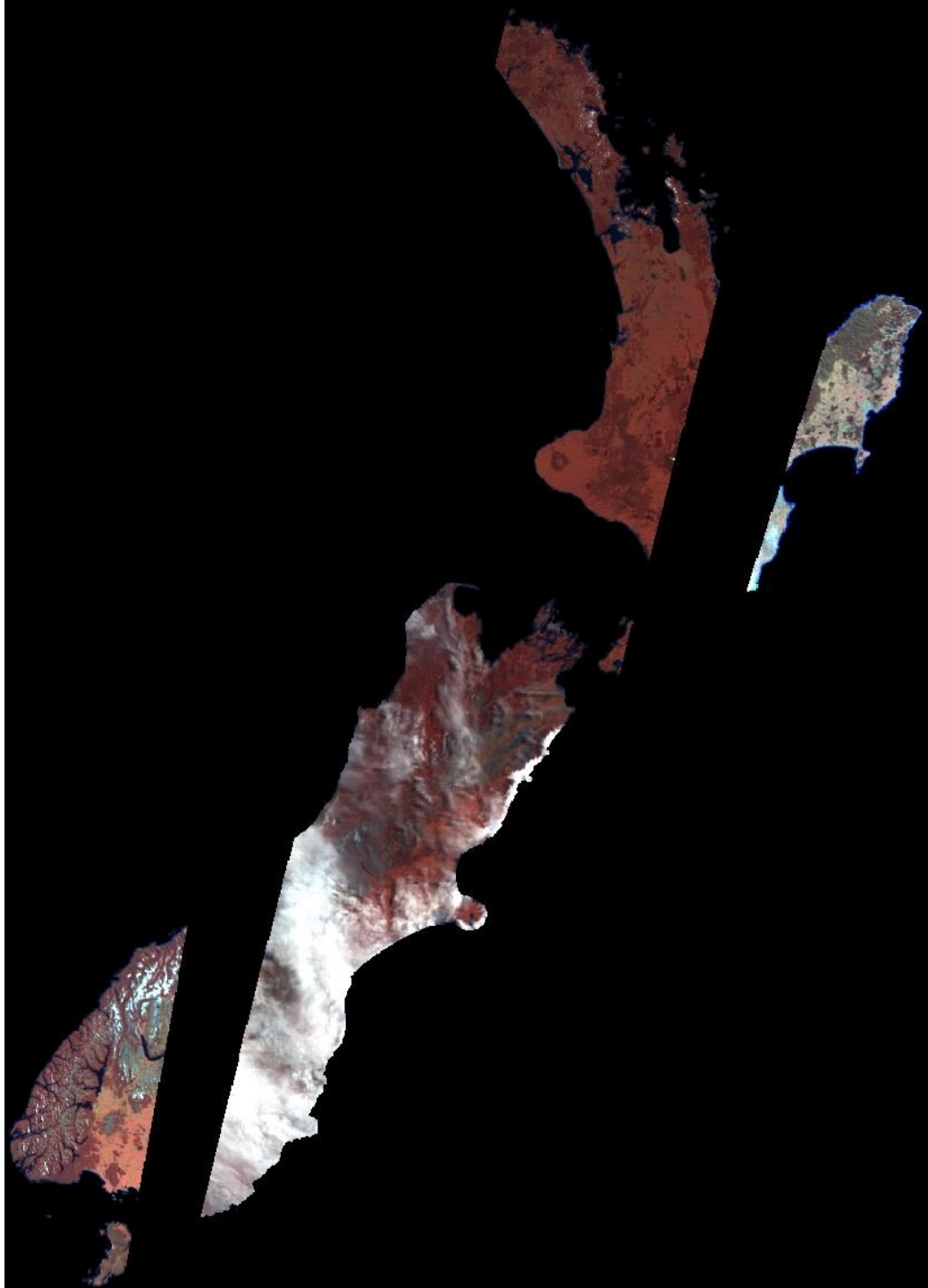


North H, Amies A, Dymond J, Belliss S, Pairman D, Drewry J, Schindler J, Shepherd J. 2021. Mapping bare ground in New Zealand hill-country agriculture and forestry for soil erosion risk assessment: An automated satellite remote-sensing method. Journal of Environmental Management. 301 https://doi.org/10.1016/j.jenvman.2021.113812

Sentinel-2

- 2 satellites with 10-day repeat cycles
- 290km swath
- 13 spectral bands from blue to SWIR (3 for calibration)
- 10m spatial resolution





Automated processing routines on NESI

- All Sentinel-2 data pre-processed to analysis-ready imagery:
  - calibration,
  - atmospheric correction
  - cloud-cleaning to mask out cloud, shadow, and snow
  - topographic correction to improve automated analyses
- Paddock boundary mapping
- Spectral land cover classification
- Application of multitemporal rules from landcover classifications, NDVI values, etc. to identify candidate paddocks

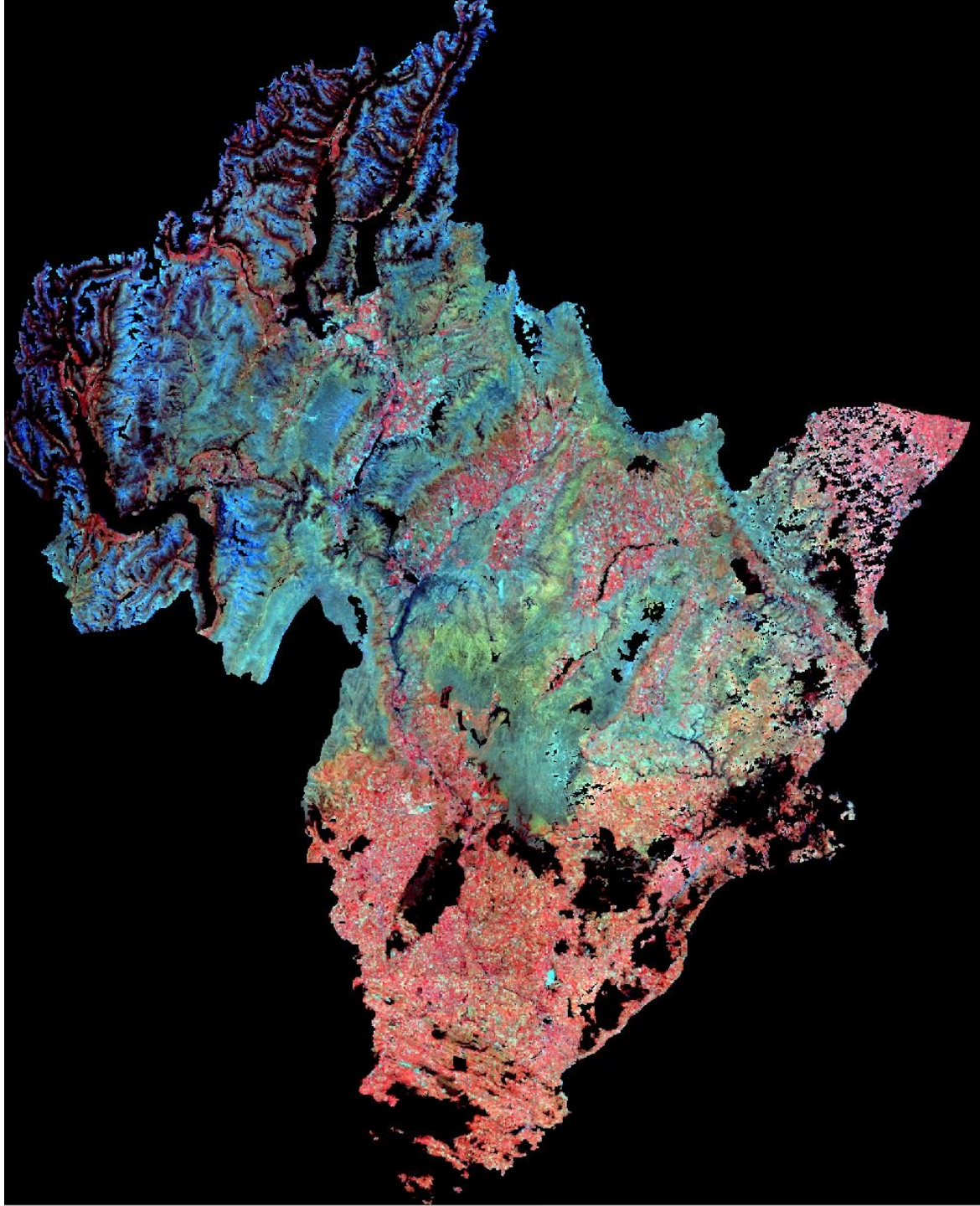
Step 1 Image selection

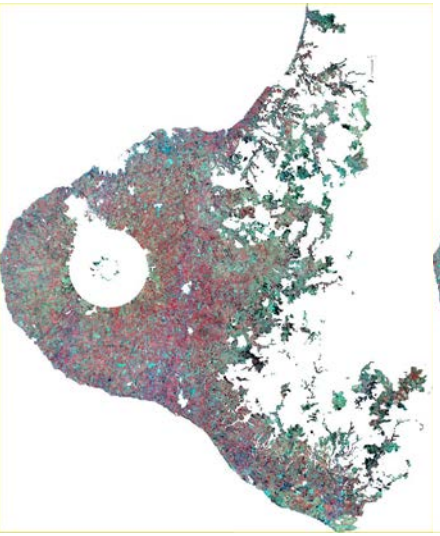
- Winter forage sequence runs March –mid-September of mapping year
- Paddock boundary mapping can use a sequence from October of previous year through to May of mapping year

December 2020	January 2021	February 2021	March 2021	April 2021	May 2021	June 2021	July 2021	August 2021	September 2021
Best images for Wellington for current winter 2021 mapping									
Nothing	25th	19th	16th	15th	5th	Nothing	4th	18th	2nd
	30th						24th		
Best images for Auckland for current winter 2021 mapping									
14th	Nothing	17th	19th	Nothing	3rd	22nd	7th	Nothing	Nothing
					13th		17th		
Best images for Southland for current winter 2021 mapping									
27th	11th	20th	12th	6th	11th	5th	Nothing	Nothing	Nothing
			17th		21st	30th			

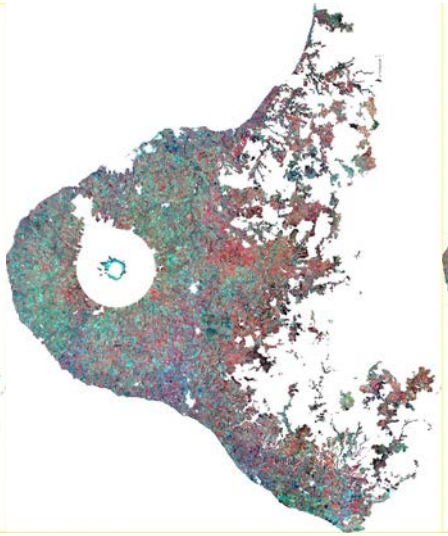
Step 2: Mask out all non-agricultural land and clip imagery to regional boundaries

- Regional cut-up to make processing tractable and to aid in subsequent reporting
- Use LCDB 5 classes to classify non-agricultural land - includes DoC Estate, urban areas, rivers, forestry, etc
- (Cloud & cloud shadow mask also applied)

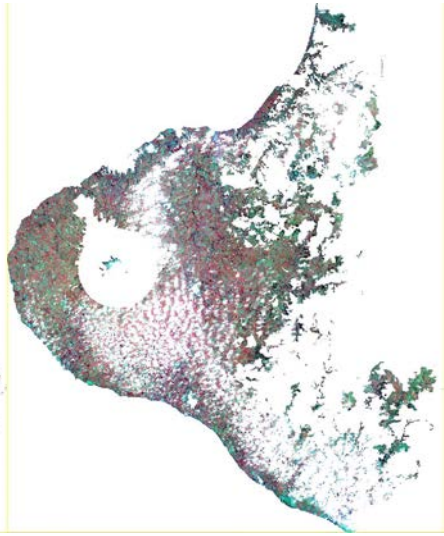




15 October 2020

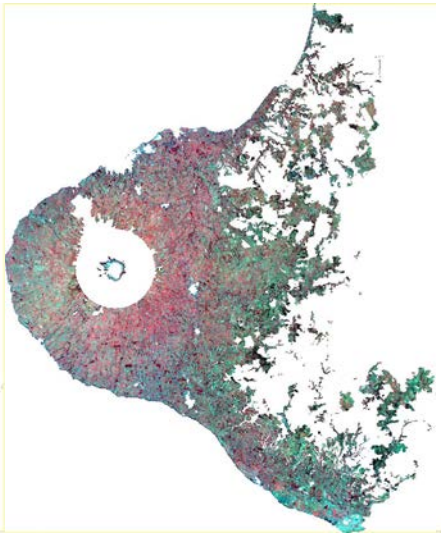


14 December 2020

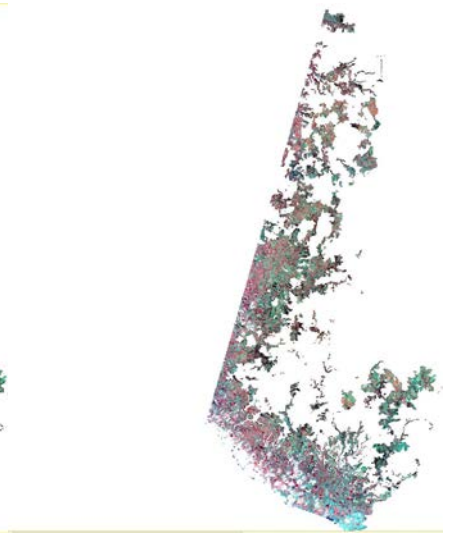


13 January 2021

30 January 2021

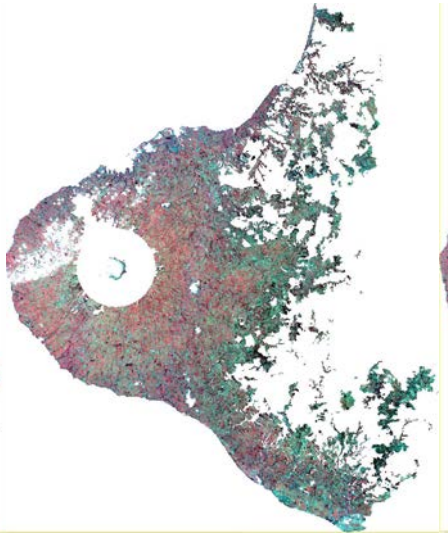


17 February 2021

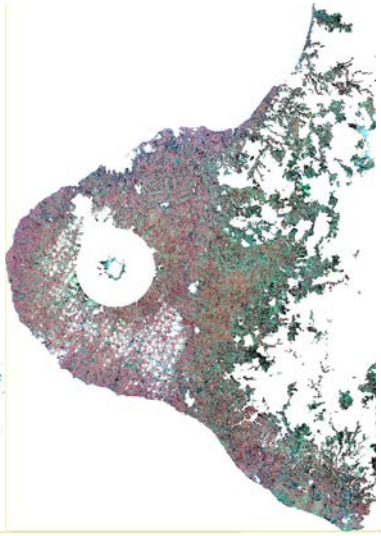


19 February 2021

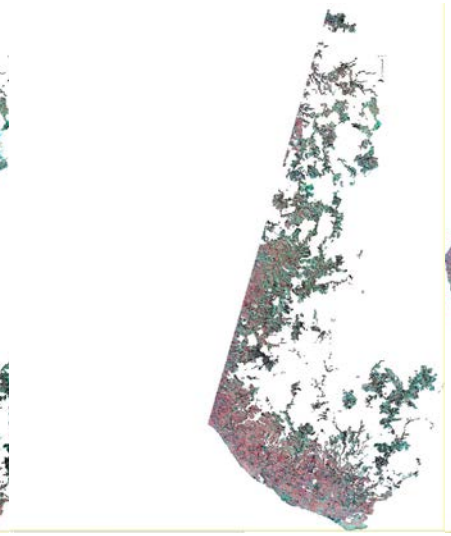
19 March 2021



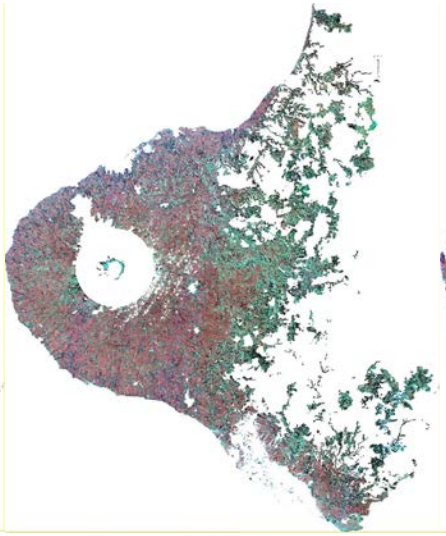
24 March 2021



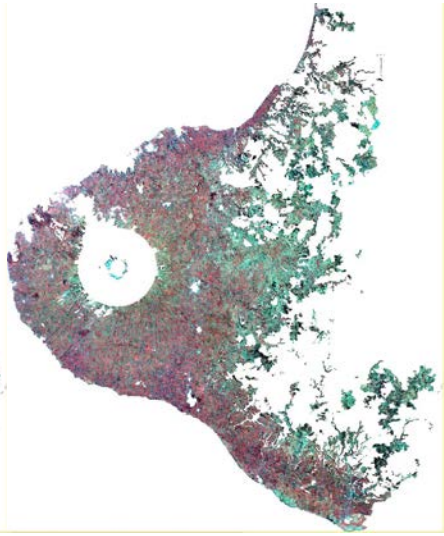
28 April 2021



25 May 2021



22 June 2021



31 August 2021

Step 3: Compile ground truth to gather spectra for classifications

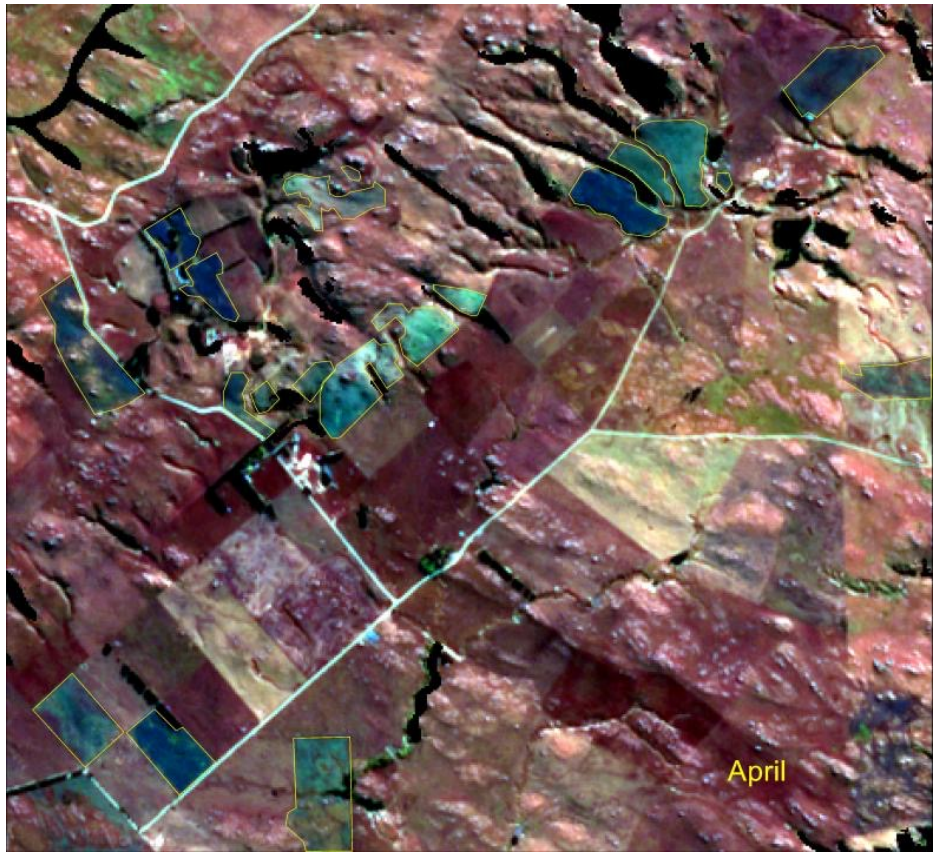
Step 4: Paddock boundary mapping outlines each paddock or crop parcel so that it can be analysed as a whole object, using all pixels within it

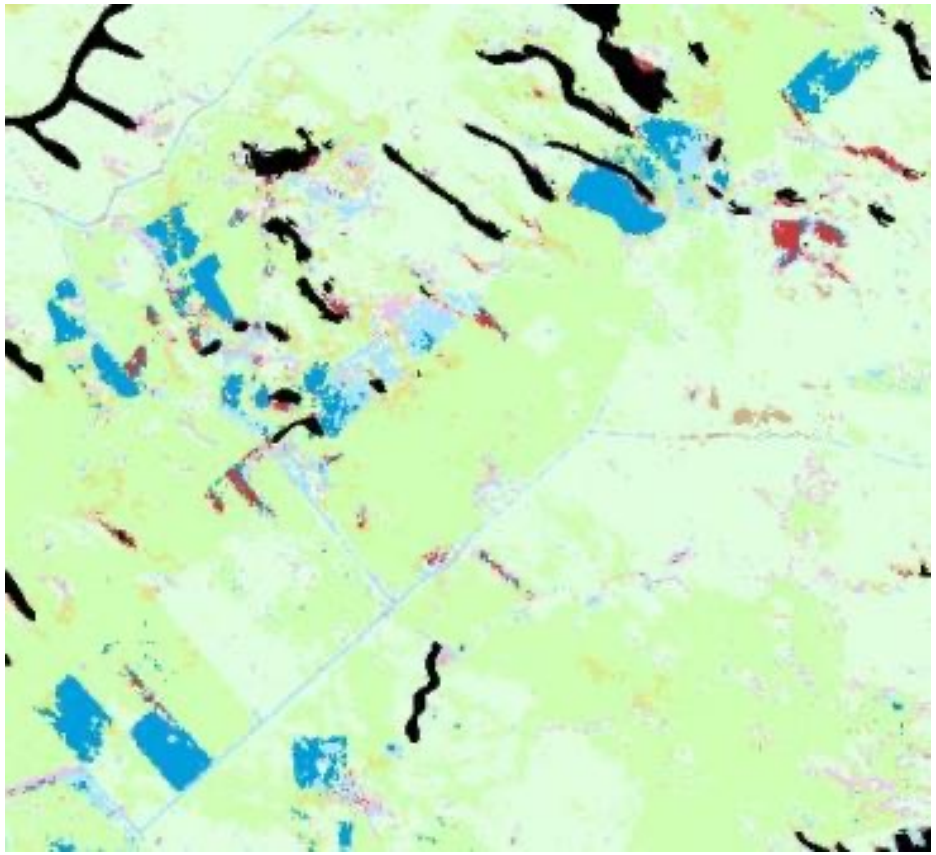
- Linear features detected on each of 16 angles
- Short line fragments at each angle are removed
- Tuned to detecting and retaining long linear features such as paddock boundary
- Long linear features from all 16 angles combined into a single layer
- Converted to vector (GIS) format
- Plus roads burned in.

North HC, Pairman D, Belliss SE 2019. Boundary delineation of agricultural fields in multitemporal satellite imagery. *IEEE Journal of Selected Topics in Applied Earth Observation and Remote Sensing 12* (1): 237–251.

Step 5: Spectral land cover classification

- Per-pixel classification of all images in the sequence
- Classes include winter forage types, pasture and bare soil





Step 6: Rule-based classification of winter forage and intensively-grazed pasture

- Look for two pieces of evidence:
  - Spectral land cover class is a forage type or an improved pasture in late autumn/early winter
  - Changes to bare soil in winter/early spring
- Ideally see both for greatest certainty, but sometimes incomplete image series

Otago subscene, 2018, showing winter forage paddocks mostly grazed down.

Step 6 *(continued)* **: Rule-based classification of winter forage and intensively-grazed pasture**

1. **Per-pixel analysis (through time)**

- Analysing time series of classifications
- Dates on which
  - pixel first became vegetated
  - subsequently became bare (e.g. if grazed down)
  - then became vegetated again (e.g. re-growth or new crop planted)
- Dominant land cover in autumn/winter (during vegetated period)

2. **Per-paddock analysis**

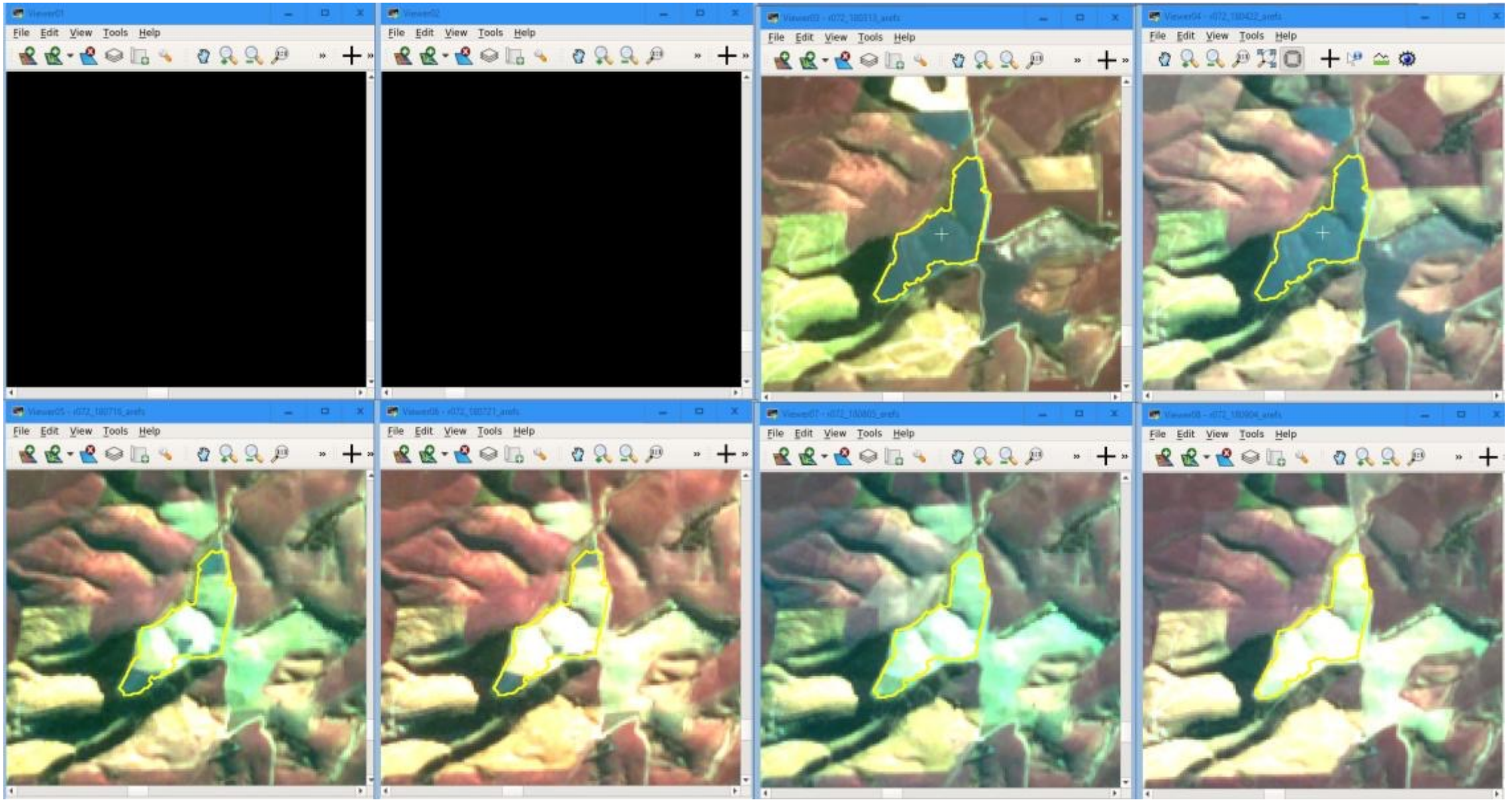
Impose GIS paddock boundaries over pixels

Dominant winter land cover (from per-pixel assessment)

Step 6 *(continued)*: The current classification rules for winter forage and intensively-grazed pasture

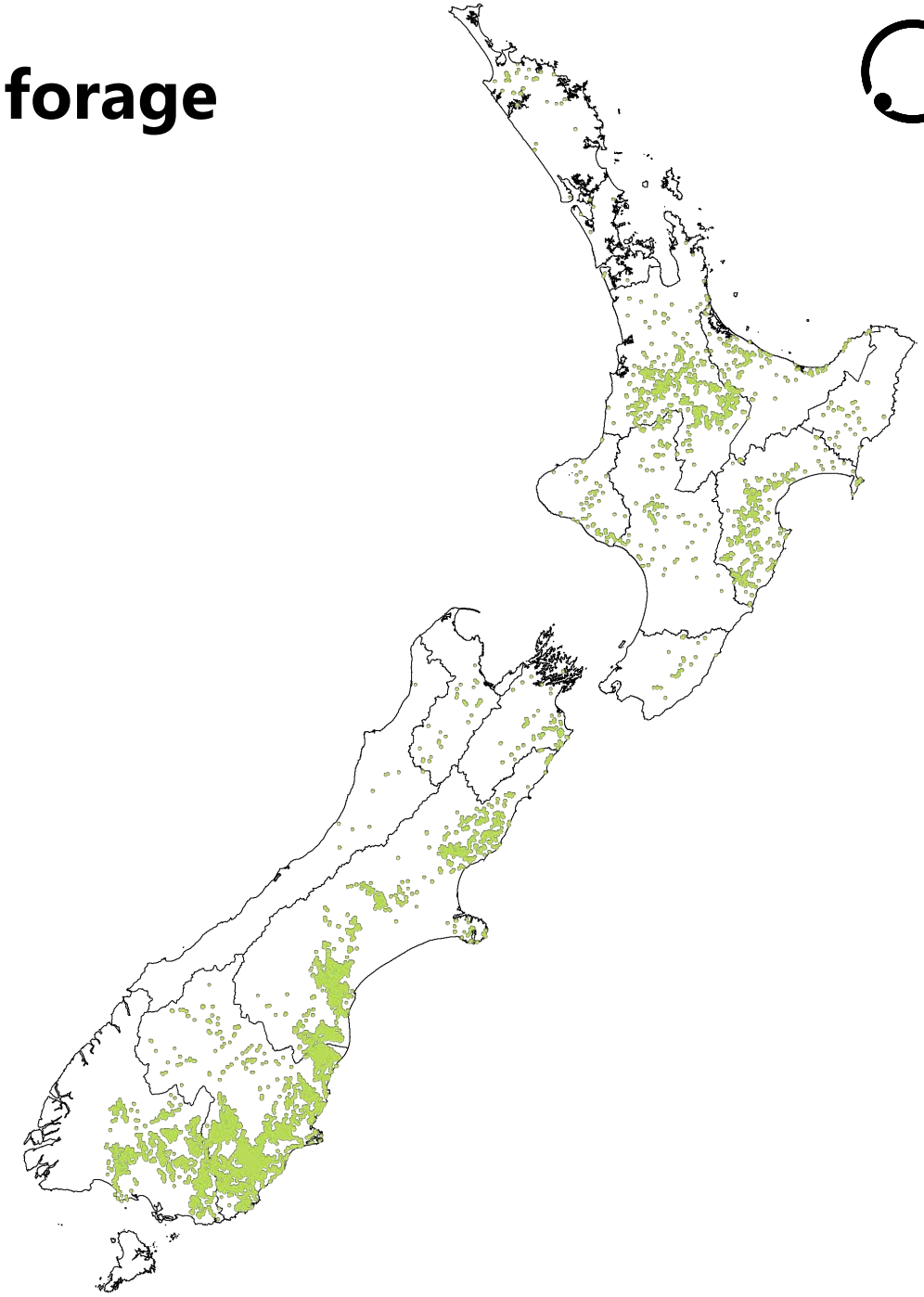
Certainty level	Dominant winter land cover	Seen to become bare	Existence of images mid-Aug to end-September	Significant NDVI drop
Good	Brassica, fodder beet or cereal	Paddock becomes >20% bare soil May-September	N/A	N/A
Medium	Unknown/mixed forage types	Paddock becomes >20% bare soil May-September	N/A	N/A
Low (case 1)	Brassica, fodder beet or cereal	Not observed to become bare on winter	No valid image data from mid-August to mid-September	N/A
Low (case 2)	Improved pasture	Observed to become >20% bare before the end of August	Yes	Yes
Low (case 3)	Any forage type	N/A	N/A	Significant drop from autumn to winter

Step 7: Manual paddock validation

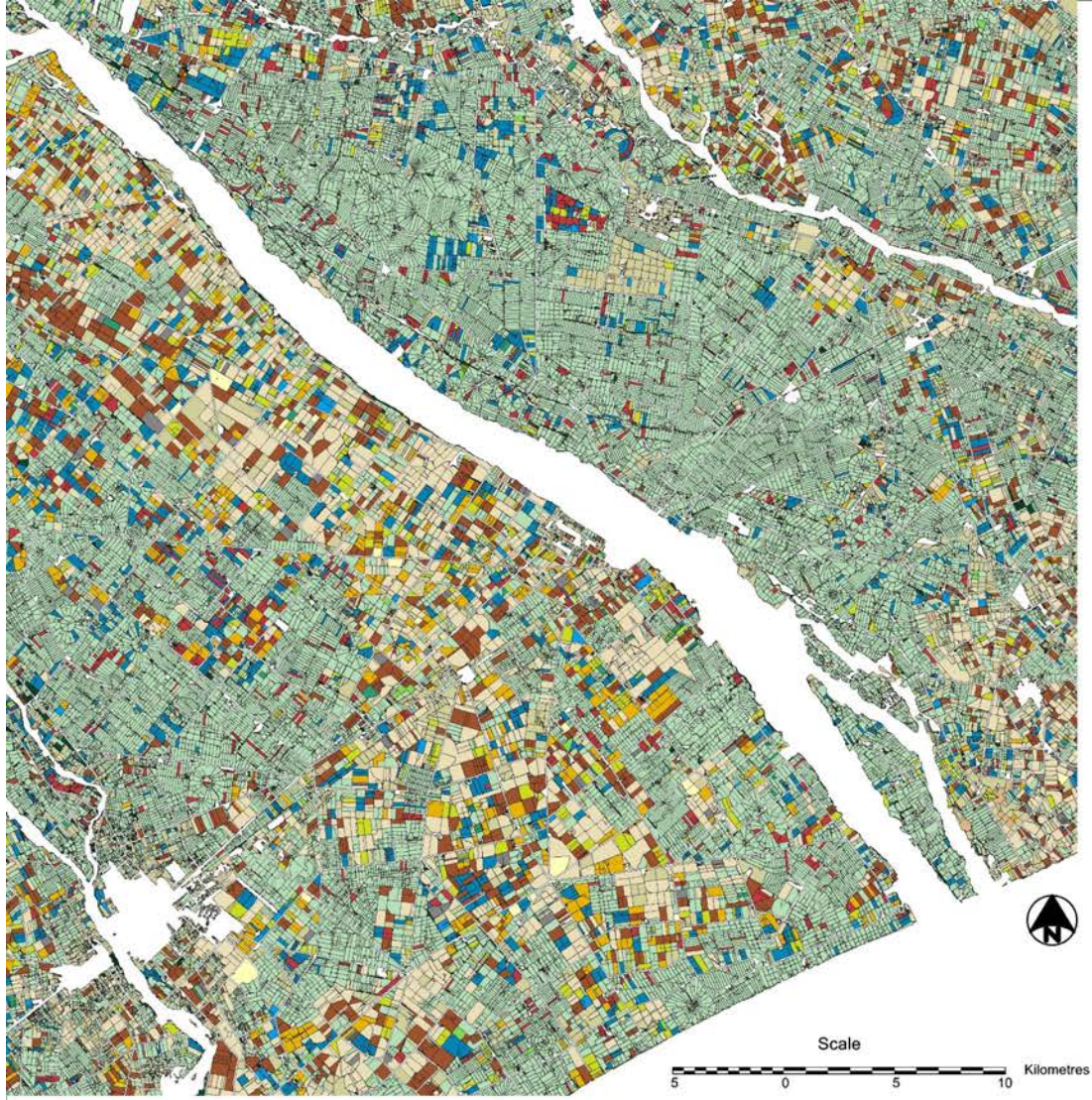


Example result: 2018 hill country winter forage

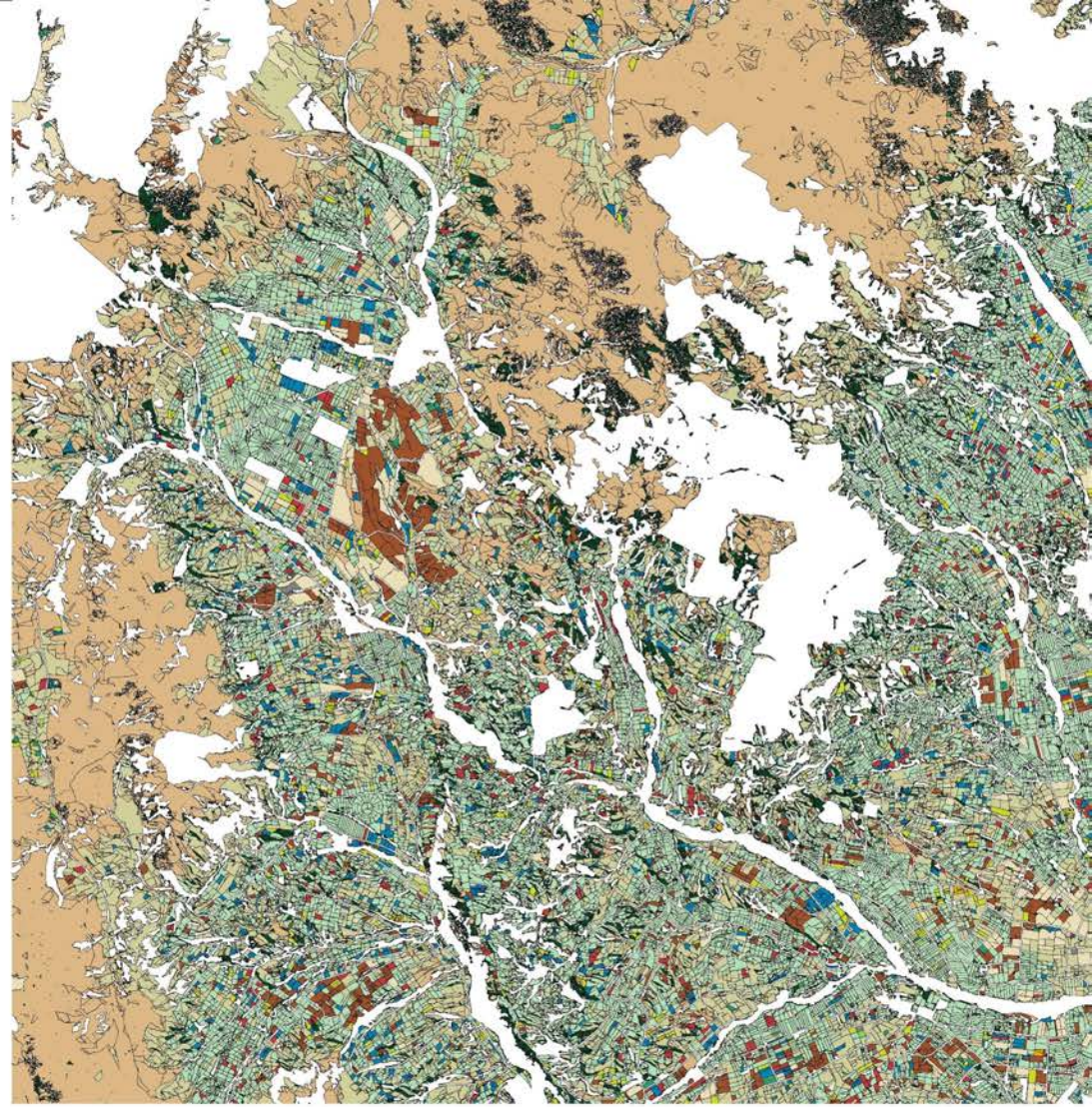
- Most of the winter forage paddocks were in Southland (2.21% of the area classified as hill country, Otago (1.61%) and Canterbury (1.2%)
- Only 0.76% of NZ hill country agricultural land - just over 42 000 hectares - had been devegetated and might be at risk for erosion



Subscenes from 2020 Canterbury winter forage map



a. Area around the Rakaia River - Ashburton township in lower left; Selwyn River upper right



b. Area around Lake Opuha, Fairlie, Pleasant Point and the Opihi River, with the Orari River top right

Legend

Winter forage crop grazing

- WF kale
- WF brassica - other/unknown
- WF fodder beet
- WF cereal
- Winter grazing - other/unknown (to bare ground)

Non-winter-forage land uses

- Bare soil for extended period
- Crop residue/dead vegetation for extended period
- Autumn-planted arable crop or pasture
- High-producing perennial grass-based pasture
- High-producing perennial herb-based forage
- Lucerne perennial forage
- Low-producing or low-cover perennial grass-based pasture
- Tussockland, herbfield, undeveloped/rough grassland
- Vineyards and shrubby horticultural crops
- Trees and scrub

Unknown whether winter forage

- Unknown/other vegetation
- Unknown land use

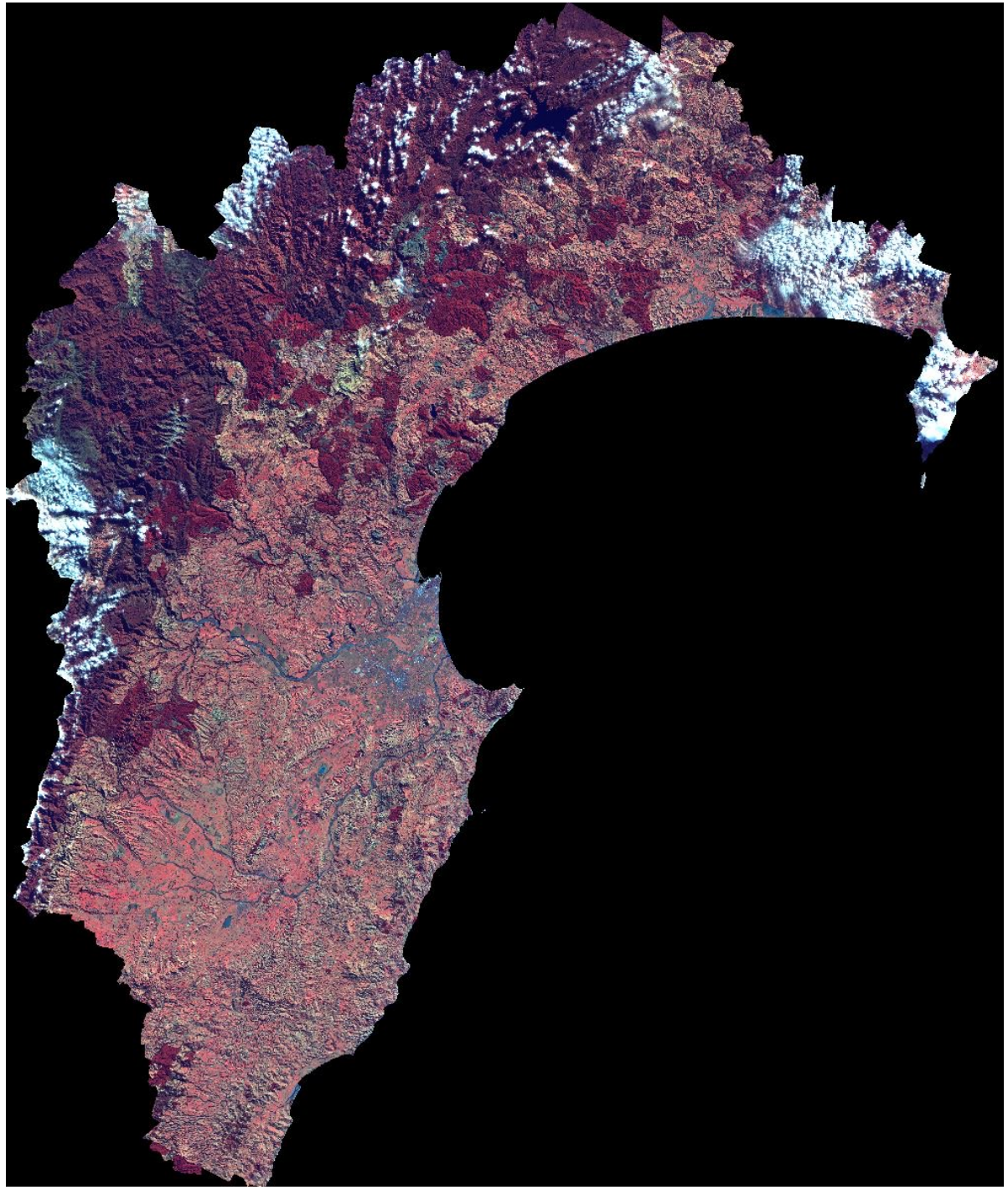
Future moves

- Accumulating more ground truth to add to a more generic set of spectral signatures (rather than sets per region and per image)
- Aiming for one set of spectral signatures including autumn and winter imagery that can be applied across all dates
- Improvements to “fast” methodology to get information out to users during the intensive winter grazing season – would this be useful???
- (Possibly) national layer every year

Questions?

A trial of “Fast” winter forage mapping

- Used only the best images mid-April – late July (4)
- Virtually no field-collected ground truth so reliant upon 2018 season spectral signatures and visual inspection
- Idea was to get maps to users while winter forage grazing still underway



“fast” Results

- Method not as accurate as post-season mapping but more timely
- Worked well for brassicas but not so well for fodder beet and cereals
- If we were running the fast method again, we would plan for/would have a good set of ground truth to train the fast model