Using LiDAR to improve the Land Resource Inventory for Northland
MPI - SLMACC

James Barringer – DEM Analysis, Segmentation and LUC map processing

James Shepherd – LiDAR processing

Malcolm McLeod, Scott Fraser – Soil Survey

Ian Lynn- Soil Survey and LUC legend

Les Basher, Raphael Spiekermann – Erosion Mapping

David Palmer, Robbie Price – DSM (Geostatistics)

Lachie Grant (LandVision) – Traditional LUC mapping

Landcare Research
Manaaki Whenua

Aim & Objectives of Project

Pilot study in Northland of approximately $100km^2$, to update NZLRI and LUC “at farm-scale” using modern automated digital mapping techniques.

- Deliver accurate inventory layers at farm-scale?
- Deliver LUC maps that are fit for purpose?
- Reduce overall cost per hectare of LUC mapping?
- LUC mapping more quantitative/less subjective?
- Make LUC mapping procedures more repeatable?
- Make remapping of LUC less costly?
- Compare traditional and digital map products?

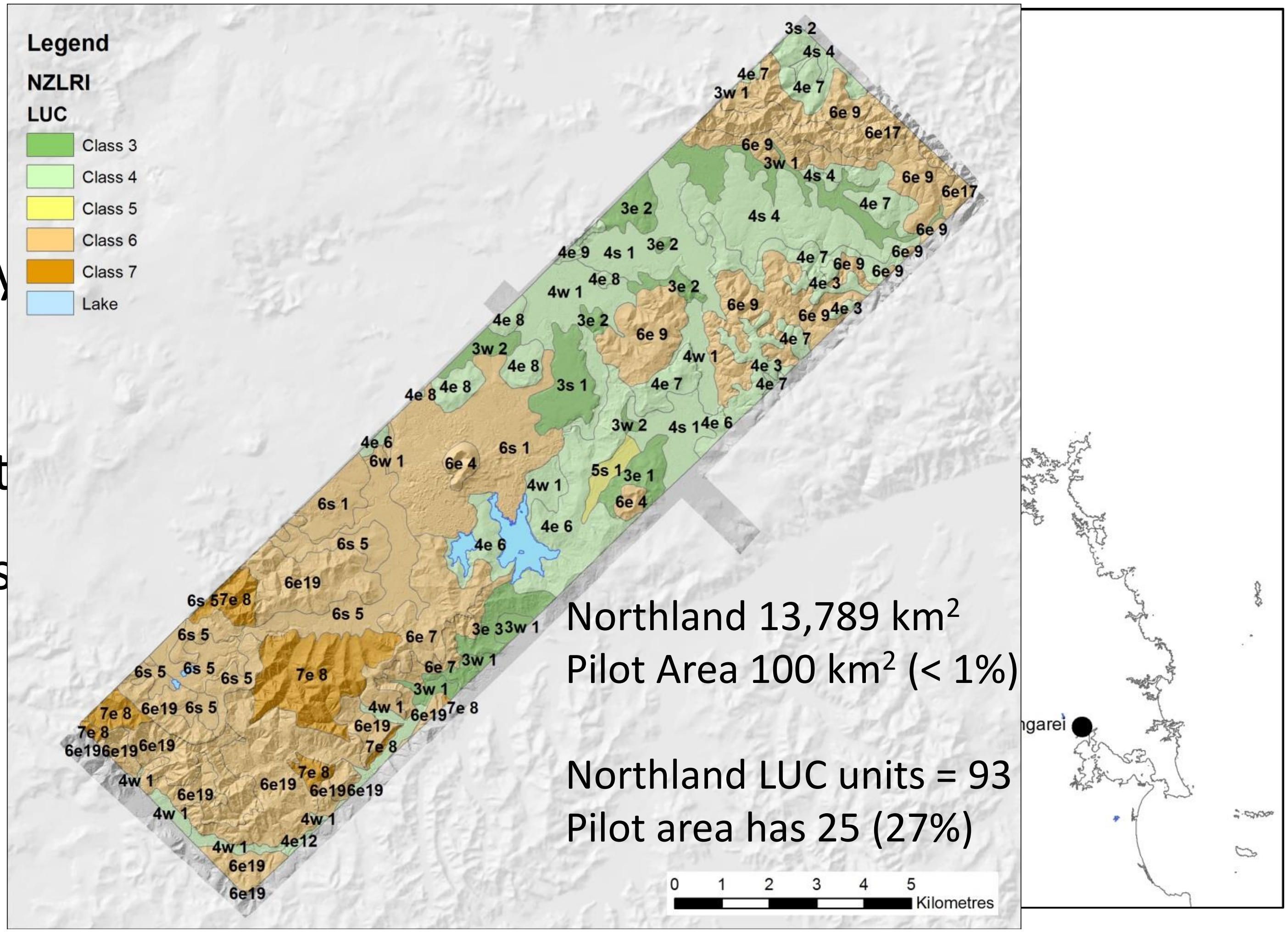
Where to run this pilot study

In North

Mix of:

- Geology
- Terrain
- Vegetat
- Land Us
- Erosion

= LUC



Northland 13,789 km^2
Pilot Area 100 km^2 (< 1%)

Northland LUC units = 93
Pilot area has 25 (27%)

Traditional Farm-Scale LUC

Business as usual traditional LUC mapping

- Treated as a commercial job.
- Undertaken as per the LUC handbook.
- Paddock maps only pre-field-mapping preparation.
- Nominally 1:10,000 - smallest unit = size of old ‘one cent piece’
- Actual 1:7,000-10,000 – c. 1:15,000 for forested or bush/scrub.
- All inventory assessed in field – LUC assigned in office.
- The regional scale LUC/LRI reviewed but not used in the mapping process.
- Observation points marked on field sheets during the mapping process.
- In drawing the polygons consideration was given to management practices.

Traditional Inventory Approach

Rock assessed when digging holes and looking at track or bank cuttings
plus consideration of physiographic position in the landscape.

Soil by physiographical position plus changes in vegetation type.
Continuously using auger observations to confirm extent.
The soils were described using traditional soil survey techniques.
Local names were <u>not</u> assigned in the field (office from old LCR descriptions).
Confidence in soil names/correlation with descriptions varied significantly.

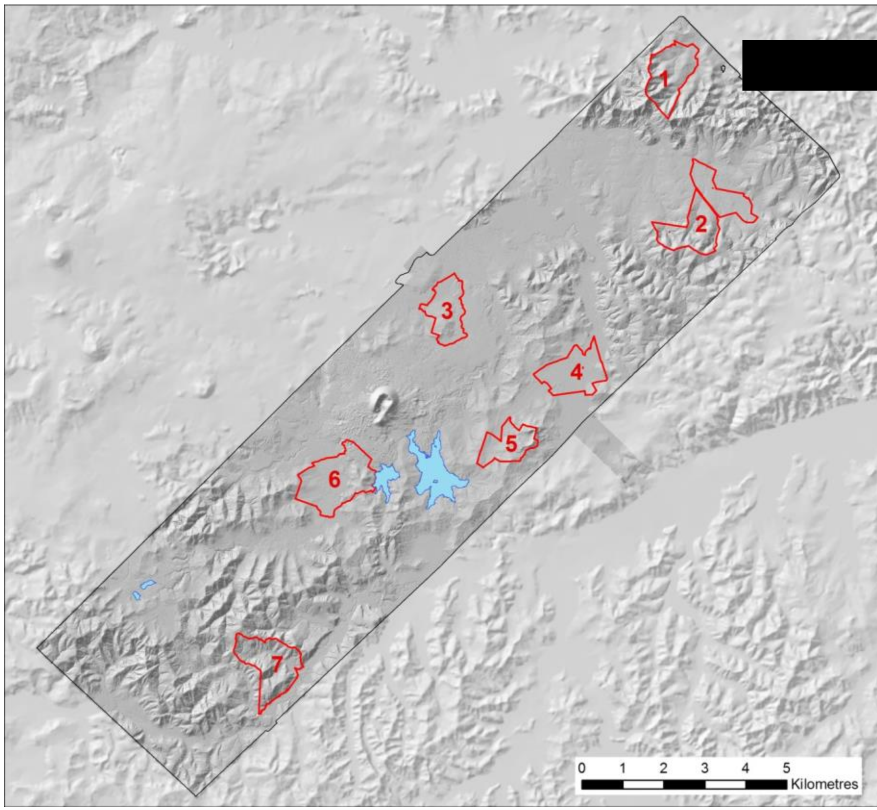
Slope determined by eye and clinometer (from at least two angles).

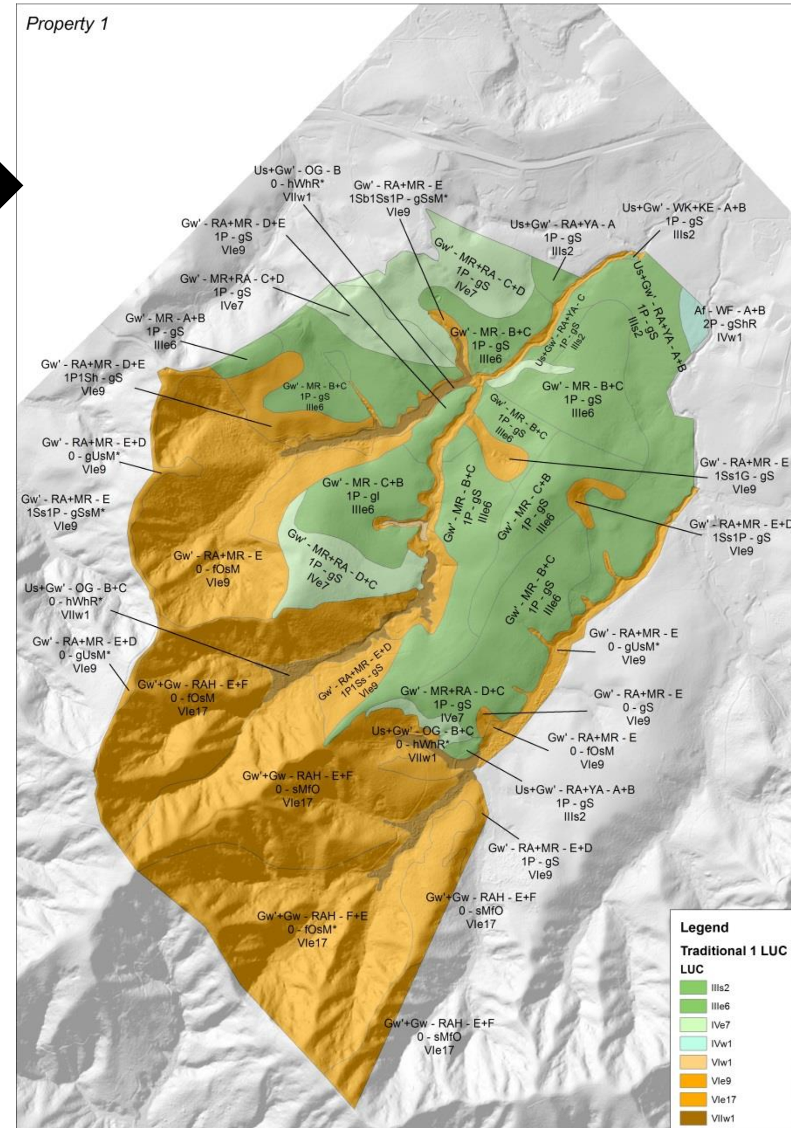
Erosion mapped "as present".
+ 'pugging and treading or compaction damage' (extensive)
- used surface erosion degree and severity assessment

Vegetation determined from the dominant vegetation type present.
Indigenous bush + exotic forestry determined from high vantage points.

Traditional Farm-Scale Results

7 “Farms” – 10% total area





Traditional Farm-Scale Legend

LandVision Ltd
INNOVATIVE LAND MANAGEMENT SOLUTIONS

Extended Legend

Northland LUC Mapping Project

For LandCare Research

February 2017
LandVision Ltd
PO Box 7191
WANGANUI

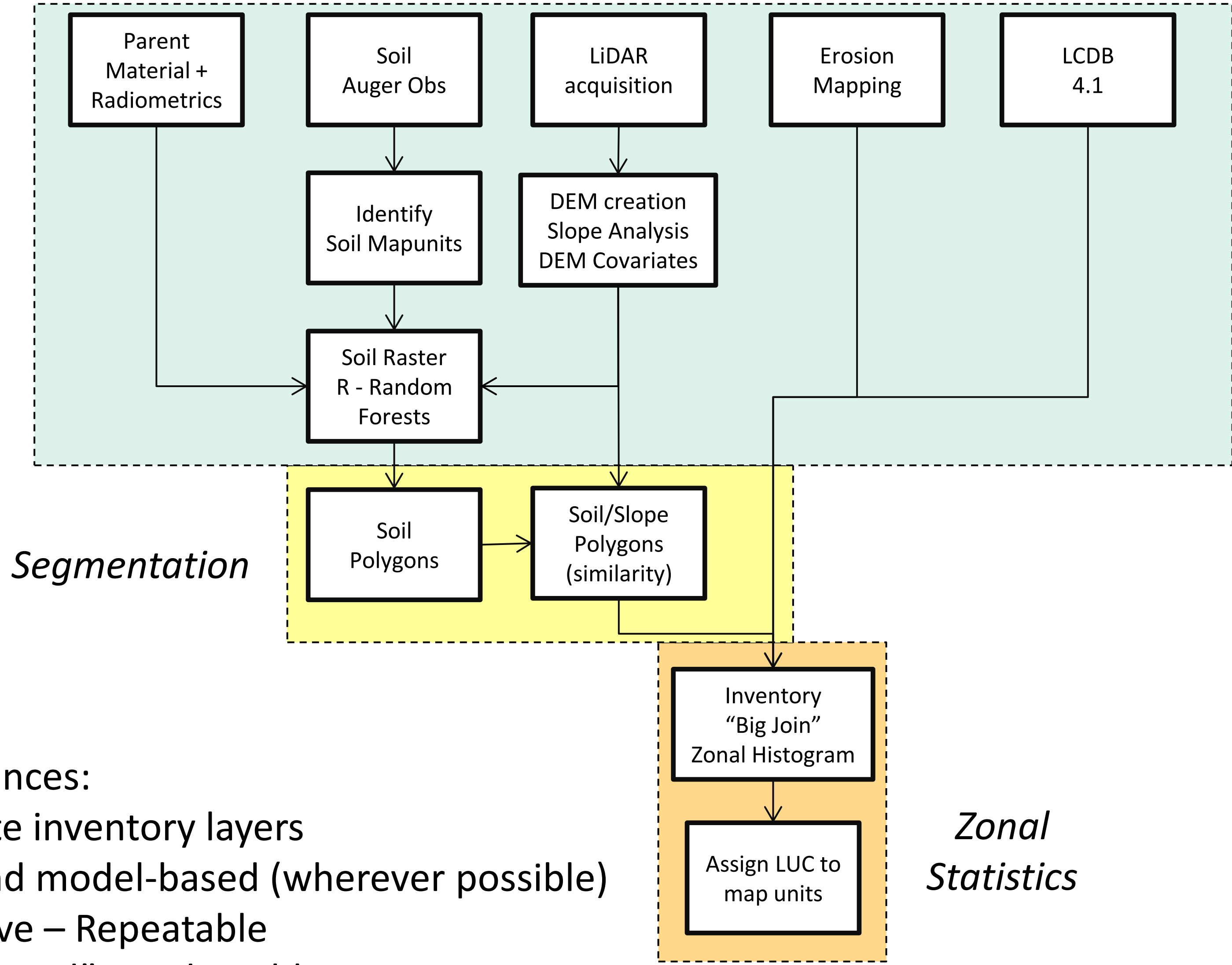
Description	Parent material	Dominant soil	Slope (degrees)	Strengths	Weaknesses	Land use suitability	Conditions of use
IIIe6 Undulating to rolling slopes within subdued rolling landscape on greywacke. Soils are yellow-brown earths. 	Greywacke (Gw)	MR WF+MR	4-15º	• Contour. • Access. • Good natural fertility.	• Slight to moderate to severe surface erosion risk under cultivation. • Seasonal soil moisture deficiency. • Finer textured and impeded drainage soils are prone to pugging and compaction damage from heavy cattle and machinery when wet.	Intensive pastoral farming.	• Minimum tillage and contour cultivation practices recommended. • Control runoff using techniques such as grassed waterways and diversion banks. • Care with heavy cattle and machinery to minimise risk of pugging and compaction damage. • Avoid over cultivation and structural degradation of soils. • Maintain pasture cover through fertility and stock management. • Consider and review stocking rate to minimise overstocking and concentrated stock movements.
IIIw1 Flat to undulating floodplains, valley plains and low to intermediate terraces with recent soils, and occasional yellow-brown earths and brown granular loams and clays, on sedimentary and volcanic alluvium. Runoff from surrounding hills and moderately high water table increase the wetness limitation.	Alluvium.	YA WF	0-7º	• Contour. • Access. • Good natural fertility. • Reasonable natural drainage.	• Potential for slight to moderate streambank erosion and deposition. • Finer textured soils are prone to pugging and compaction damage from heavy cattle and machinery when wet. • Potential for occasional	Intensive pastoral farming.	• Care with heavy cattle and machinery to minimise risk of pugging and compaction damage.

- Used strict definitions for LUC class/sub class before determining the LUC unit. e.g., difference between 3w, 4w and 6w determined by depth to mottling or gleying.
- Four new units devised where no 'good fit' to existing Northland LUC suite units (IIIw5, IIIe6, Ve1 and VIe20 units.

Digital LUC mapping

- Also based on field observations/data
- But seeking to use new data sources (e.g., LiDAR).
- Automate as much of the mapping work flow as possible.

Digital LUC generalised workflow



Key differences:

- Separate inventory layers
- Data and model-based (wherever possible)
- Objective – Repeatable
- "Automated" - updateable

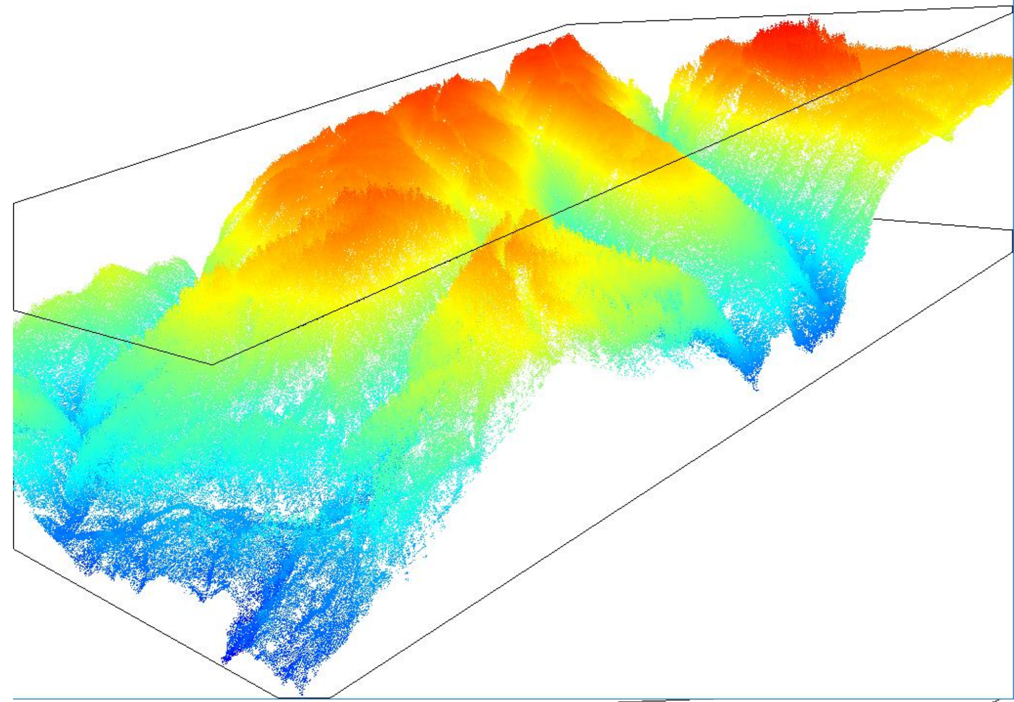
LiDAR

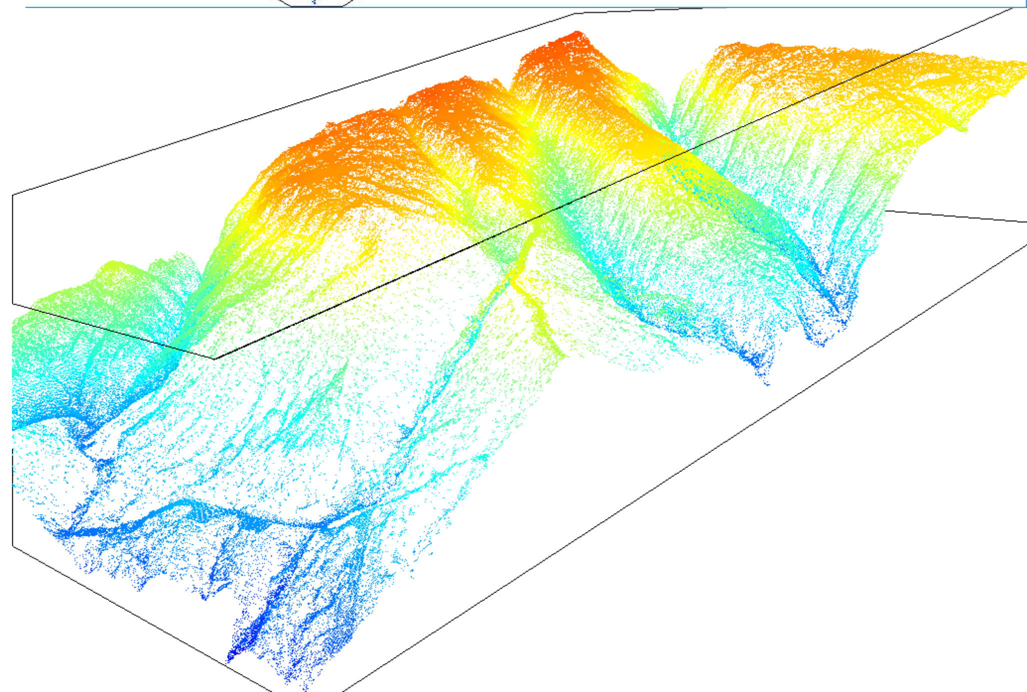
Point Cloud

DEM, DSM, CHM

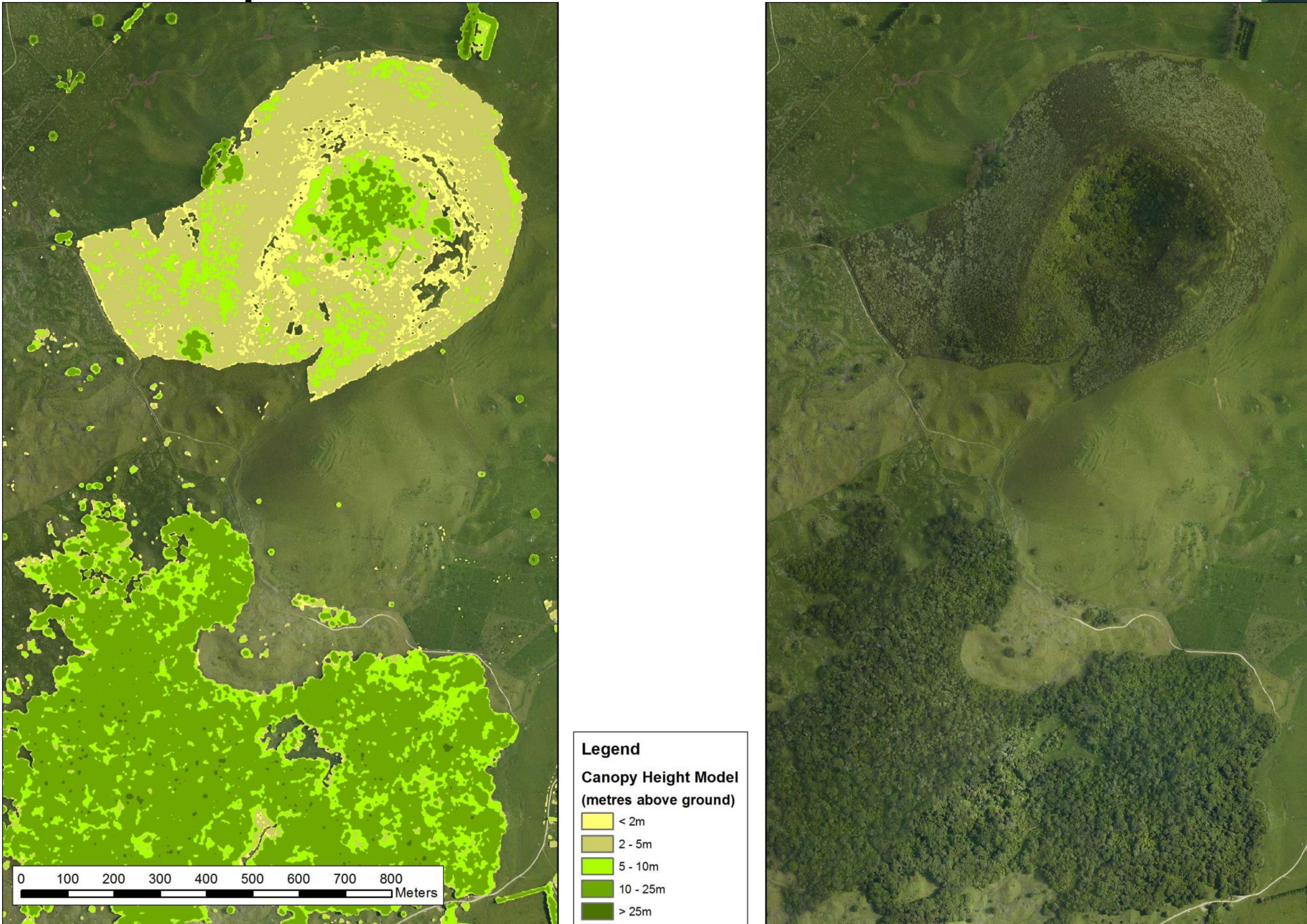
Slope mapping

Terrain Derivatives

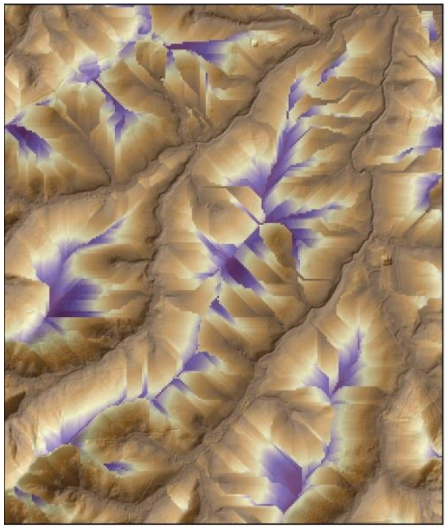




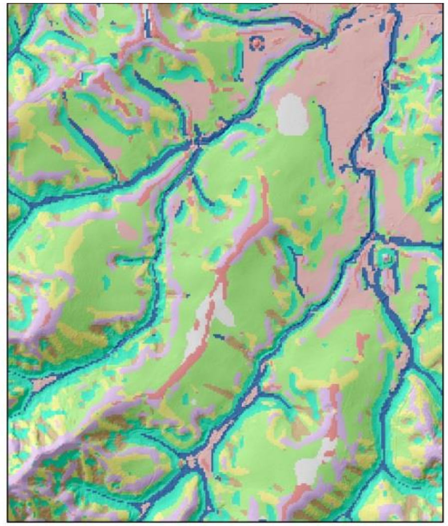
Examples of CHM in Northland



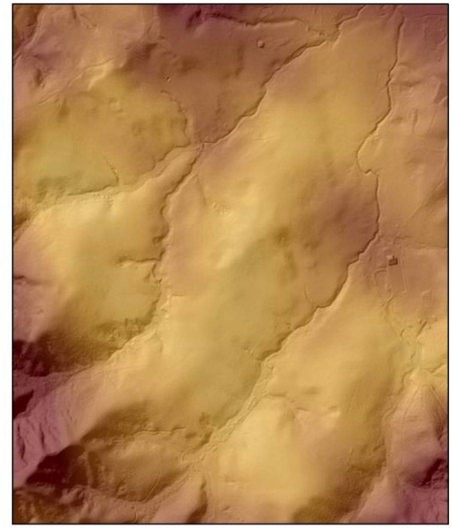
"Covariates"



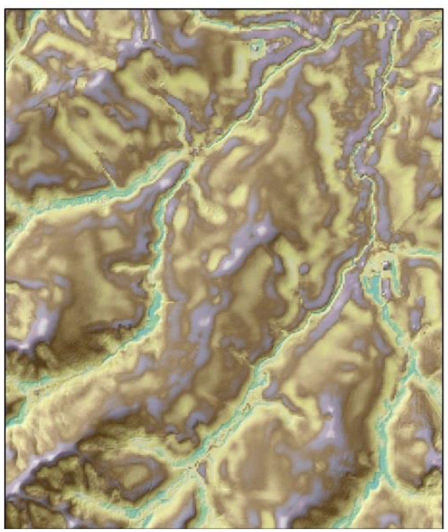
Distance 2 Stream



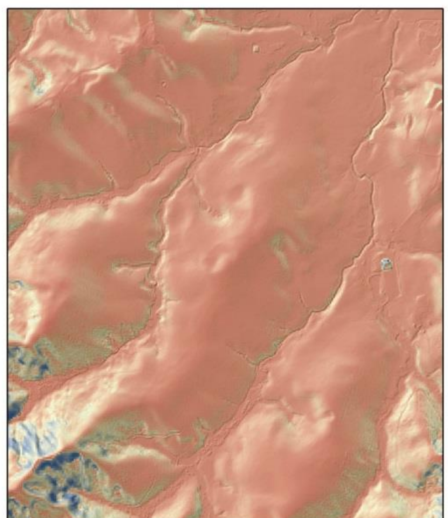
Landform Elements



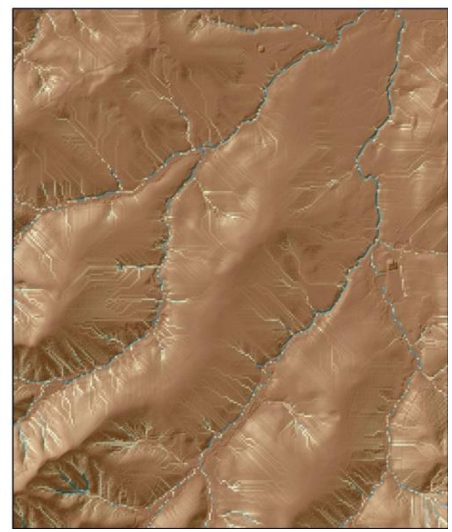
Thorium



ZREL - relative elevation

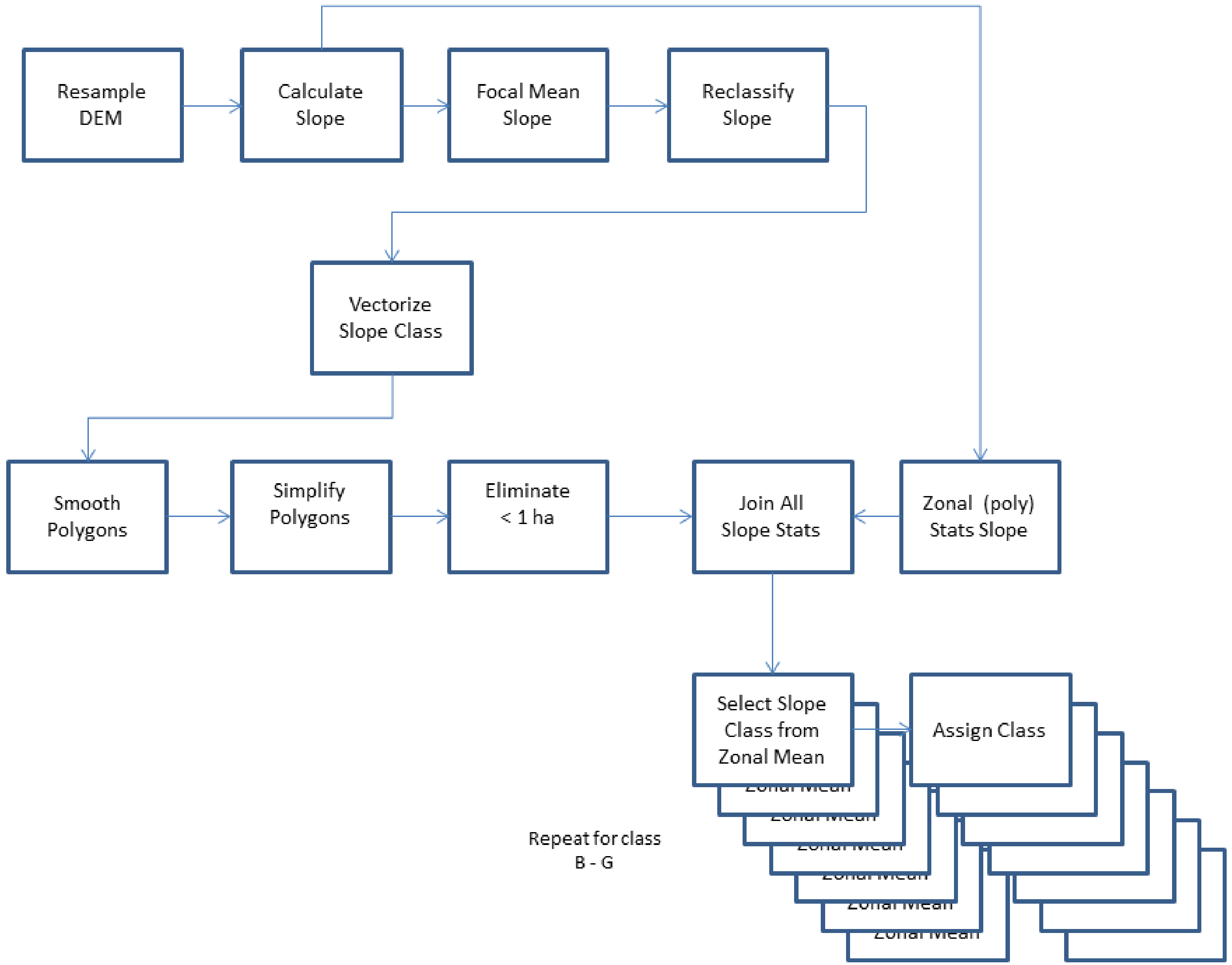


Insolation

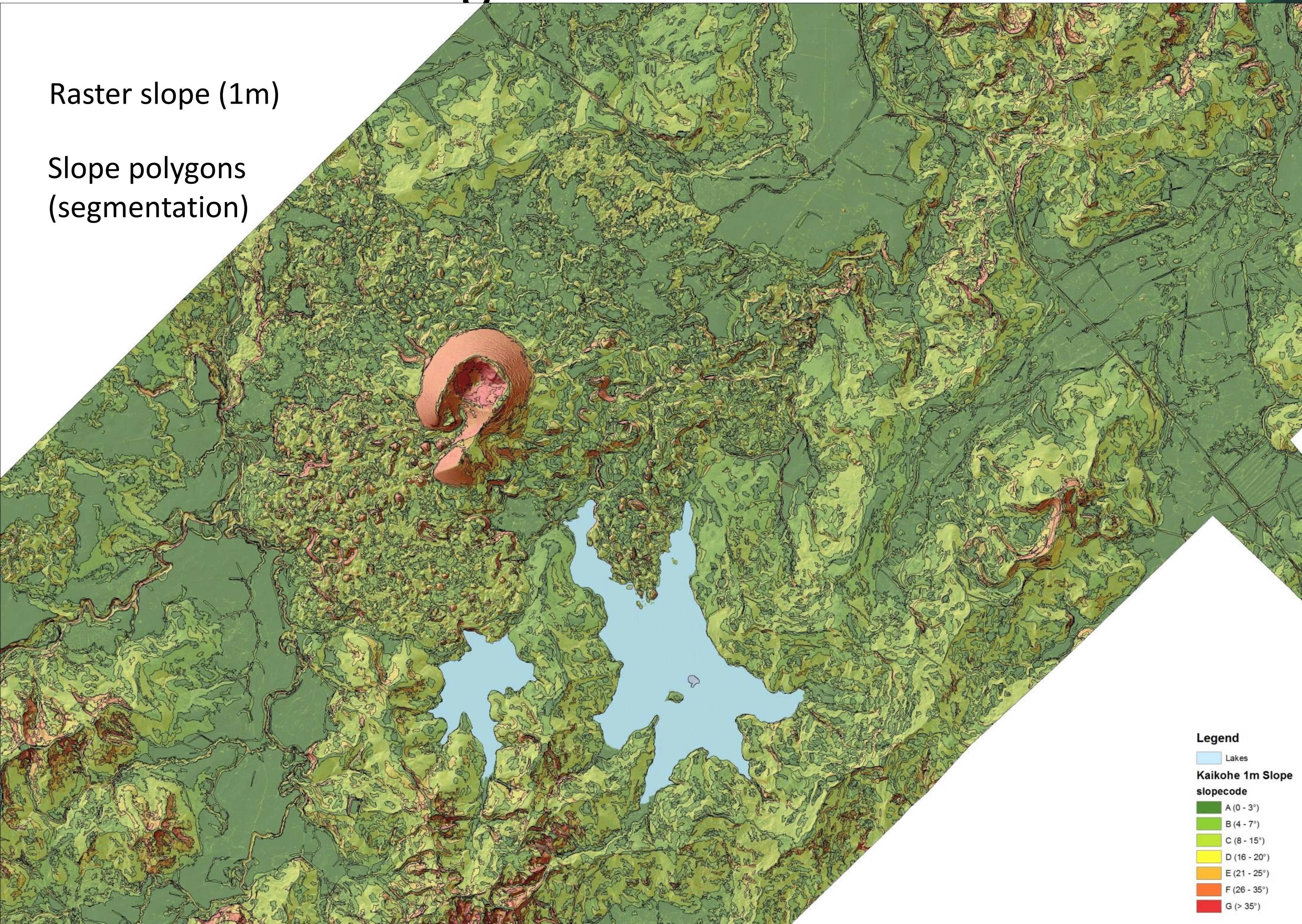


STI - sediment transport index

Slope Analysis



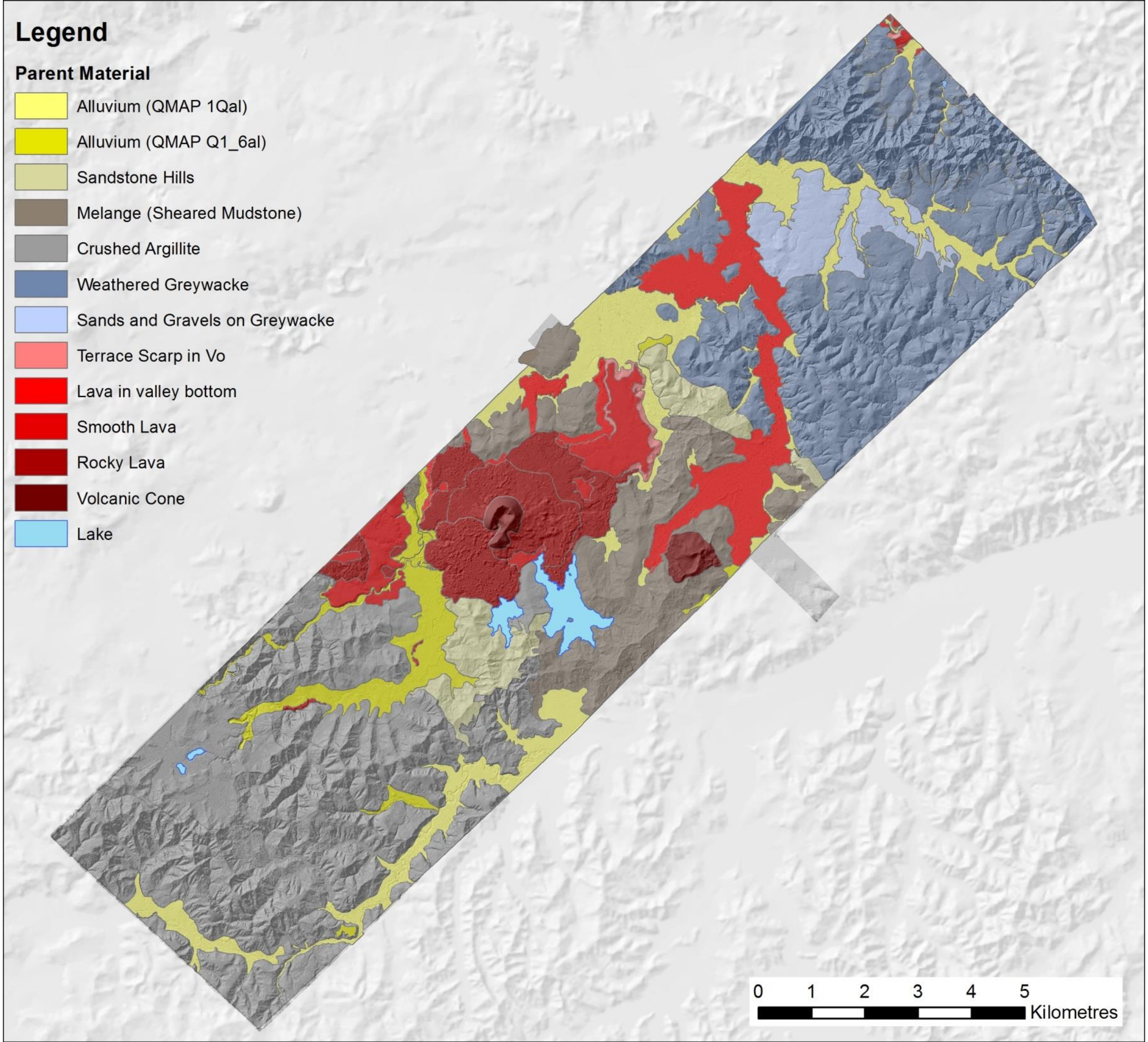
LiDAR-based Digital Elevation Model

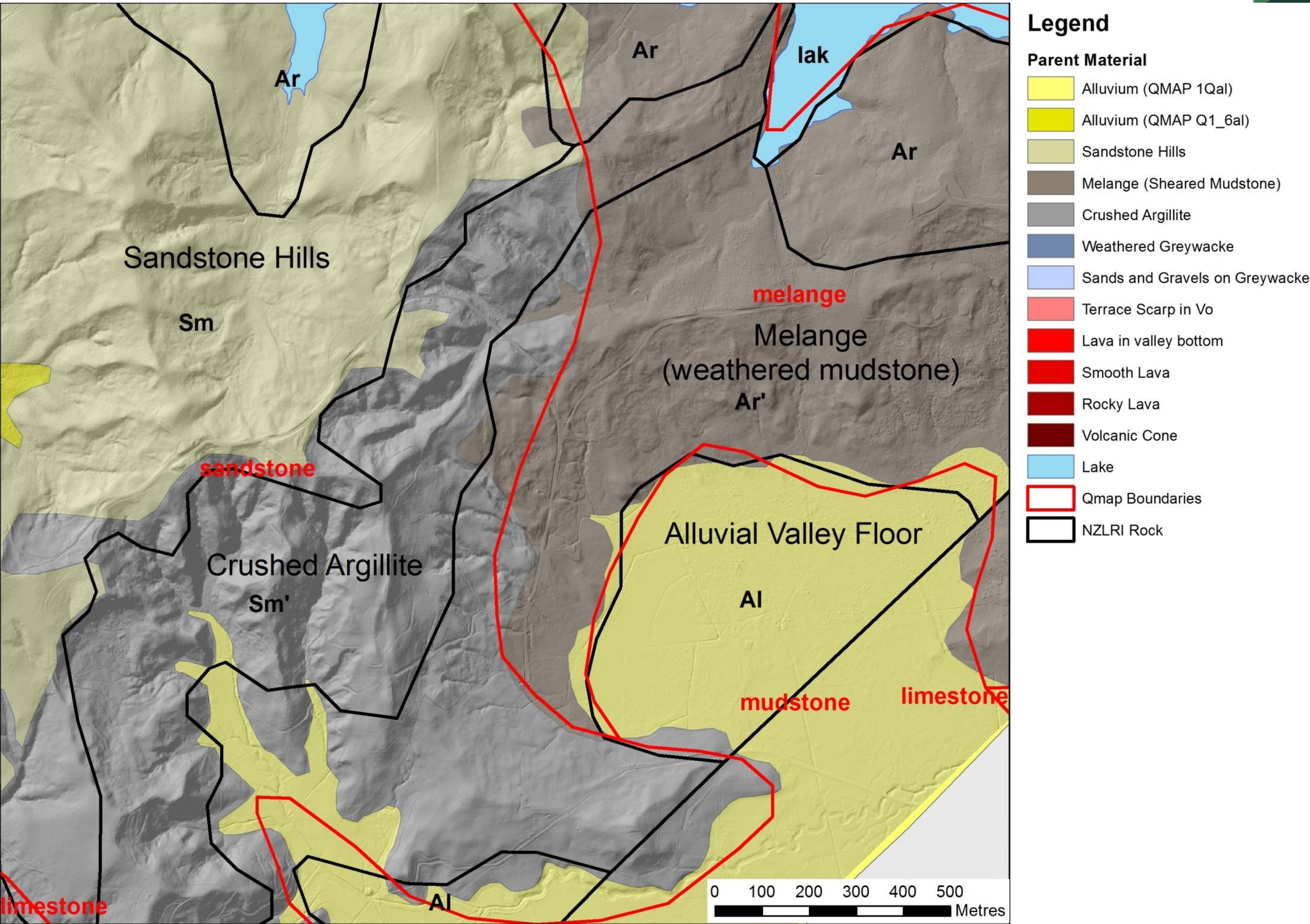


Rock Type

- **Sources**
  - Qmap – 1:250k and time stratigraphic – limited lithology/regolith information
  - NZLRI – 1:50k – better lithology/regolith – no real surface age implied
  - Radiometrics – coarse scale 50m resolution and not simple to interpret

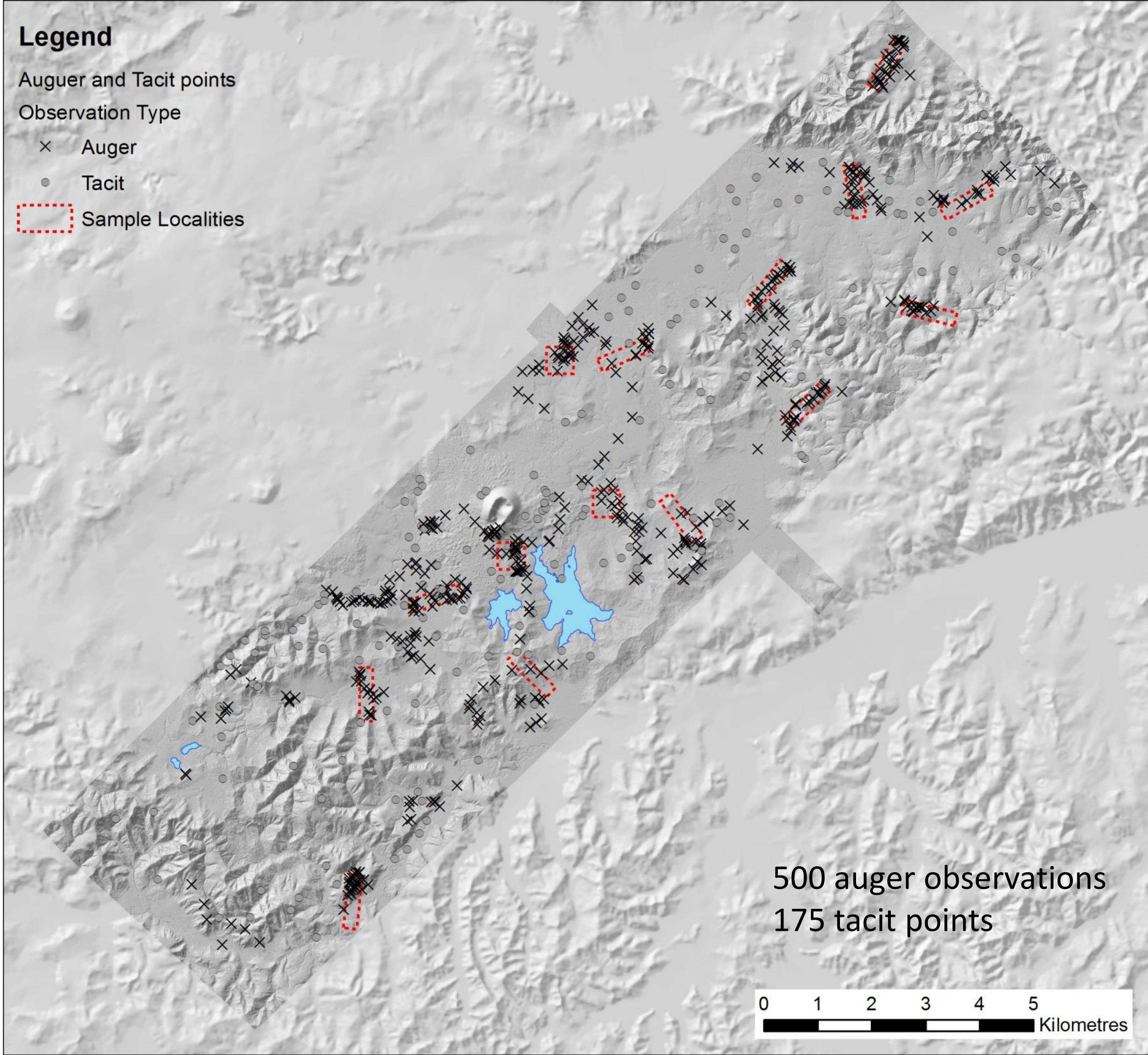
- **Scale**
  - Digital Geology Mapping - not common in literature
  - Lots of detailed terrain information
  - But rock type changes aren't always easy to identify from terrain


Legend
Parent Material
Alluvium (QMAP 1Qal)
Alluvium (QMAP Q1_6al)
Sandstone Hills
Melange (Sheared Mudstone)
Crushed Argillite
Weathered Greywacke
Sands and Gravels on Greywacke
Terrace Scarp in Vo
Lava in valley bottom
Smooth Lava
Rocky Lava
Volcanic Cone
Lake
0 1 2 3 4 5
Kilometres


Ar
Ar
lak
Ar
Sandstone Hills
Sm
melange
Melange
(weathered mudstone)
Ar'
sandstone
Crushed Argillite
Sm'
Alluvial Valley Floor
Al
mudstone
limestone
limestone
Al
0 100 200 300 400 500
Metres
Legend
Parent Material
Alluvium (QMAP 1Qal)
Alluvium (QMAP Q1_6al)
Sandstone Hills
Melange (Sheared Mudstone)
Crushed Argillite
Weathered Greywacke
Sands and Gravels on Greywacke
Terrace Scarp in Vo
Lava in valley bottom
Smooth Lava
Rocky Lava
Volcanic Cone
Lake
Qmap Boundaries
NZLRI Rock

Digital Soil Mapping
Field Survey – Auger Observations

S


Legend
Auguer and Tacit points
Observation Type
Auger
Tacit
Sample Localities
500 auger observations
175 tacit points
0 1 2 3 4 5
Kilometres

Map units	Description
BOM_1_2_5	Brown soils on sedimentary hills without Allophanic tephra, includes Recent and Raw soils on eroded steepland, some UYM likely.
BOM_3_4	Brown soils from alluvium, mostly mottled with some Gley and Fluvial Recent likely. Old alluvial surfaces may have Ultic soils.
BOT_1_2	Brown soils on volcanic rock including tephra and lava flows, stony and not stony. Mostly BOT, few BOM and BOT/LOT transition.
GO_al	Orthic Gley soils from alluvium, predominantly GOT, few GOO and GOA, rare GRT, GRA and Organic. Some BOM/A and RF.
GOA_1	Acid Gley soils associated with Argillite hills and adjacent terraces. Includes GOA, GAY, Perch-gley Ultic and Densipan Ultic and Podzol soils.
GOT_1	Gley soils from seepages associated with tephric soils on sedimentary hills. Includes some LOM, BOM and UYM.
LOM_1	Tephric soils with up to 1m of tephra over Ultic paleosol, P-ret predominantly <85%. BOM (tephra over buried Ultic), common LOM, some LOT, BOT, UYM.
LOM_2	Tephric soils with up to 1m of tephra over Ultic paleosol, P-ret predominantly >85%. LOM, common LOT, some BOM, BOT, UYM. Rare UEM and similar Podzols in sedimentary hills.
LOT_1	Deep Moderately well - Well drained Allophanic soils without stones. Predominantly LOT on lava, some moderately deep and/or stony, few BOT. Some LOT and LOM on sedimentary rocks close to tephra source.
LOT_2	Stony LOT on valley lava flows. Includes stony and very Stony LOTs, few without stone or extremely stony. Maybe significant areas locally where lava is buried by local alluvium and contains BOM/GOT.
LOT_3	Very stony/bouldery lava flows. Difficult to distinguish between LOT_2 and LOT_3 on some valley lava flows. Predominantly very stony/bouldery LOT with many soils proximal to scoria cones containing scoria horizons. Some deep LOT/BOT and very stony Tephric Recent soils.
LOT_4	LOT with scoria horizons on or near scoria cones. Predominantly stony and very stony LOT and related Recent (RXT, RTT) soils. Some deep LOT soils with less stones.
RF_1_2_3	Fluvial Recent (RFT, RFM) mainly loamy and without stones, locally some stony (valleys in eroding Argillite hills) or clayey. Some related Gley and Brown soils.
UDM_1	Densipan Ultic and related soils on old terraces adjacent to Argillite hills. Predominantly UDM, UDP, and related pan Podzols, some UPT, UEP and GAY.
UDM_2	Densipan Ultic and related Densipan Podzol soils on Argillite hills. Predominantly UDM, ZDYH, UEM and UYM. Some GAY on undulating footslopes.
UYM_1	Ultic soils without densipans. Predominantly UYM with some related BOM and Recent soils in steepland, and related Densipan Ultic and Podzol on more stable Argillite hills. Likely some tephric soils in NE.

Final soil map units used for DSM, descriptions and dominant components in terms of NZSC codes (Hewitt 2010).

Digital Soil Mapping Random Forest analysis

- Uses a standard machine learning technique - “decision tree” (= weak learner).
- An input is entered at the top and as it traverses down the tree the data gets bucketed into smaller and smaller sets.
- Trying many different decision trees creates the forest (= strong leaner)

From all observations - sample *N* cases at random with replacement (This subset should be about 66% of the total set).
At each node in the tree:

For some number *m, m* predictor variables are selected at random from all the predictor variables.
The predictor variable that provides the best split, according to some objective function, is used to do a binary split on that node.
At the next node, choose another *m* variables at random from all predictor variables etc.

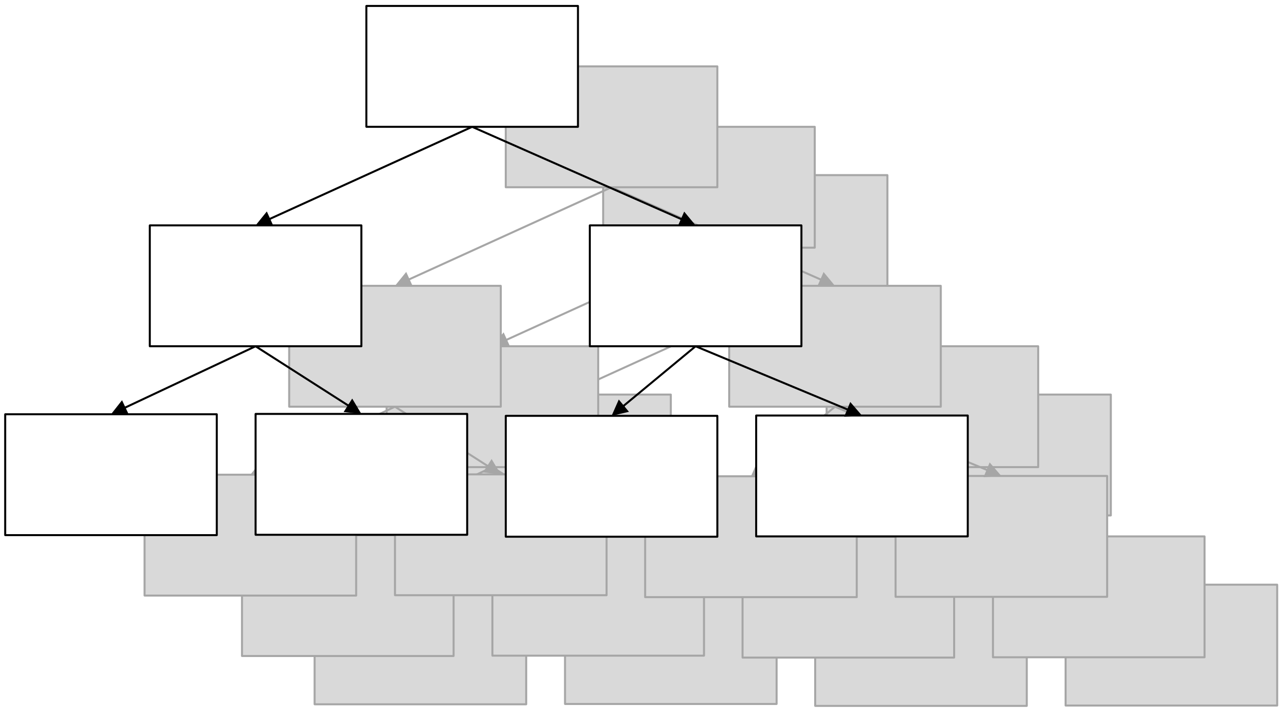
Digital Soil Mapping - predictors

S = *f(s, c, o, r, p, a, n)* where

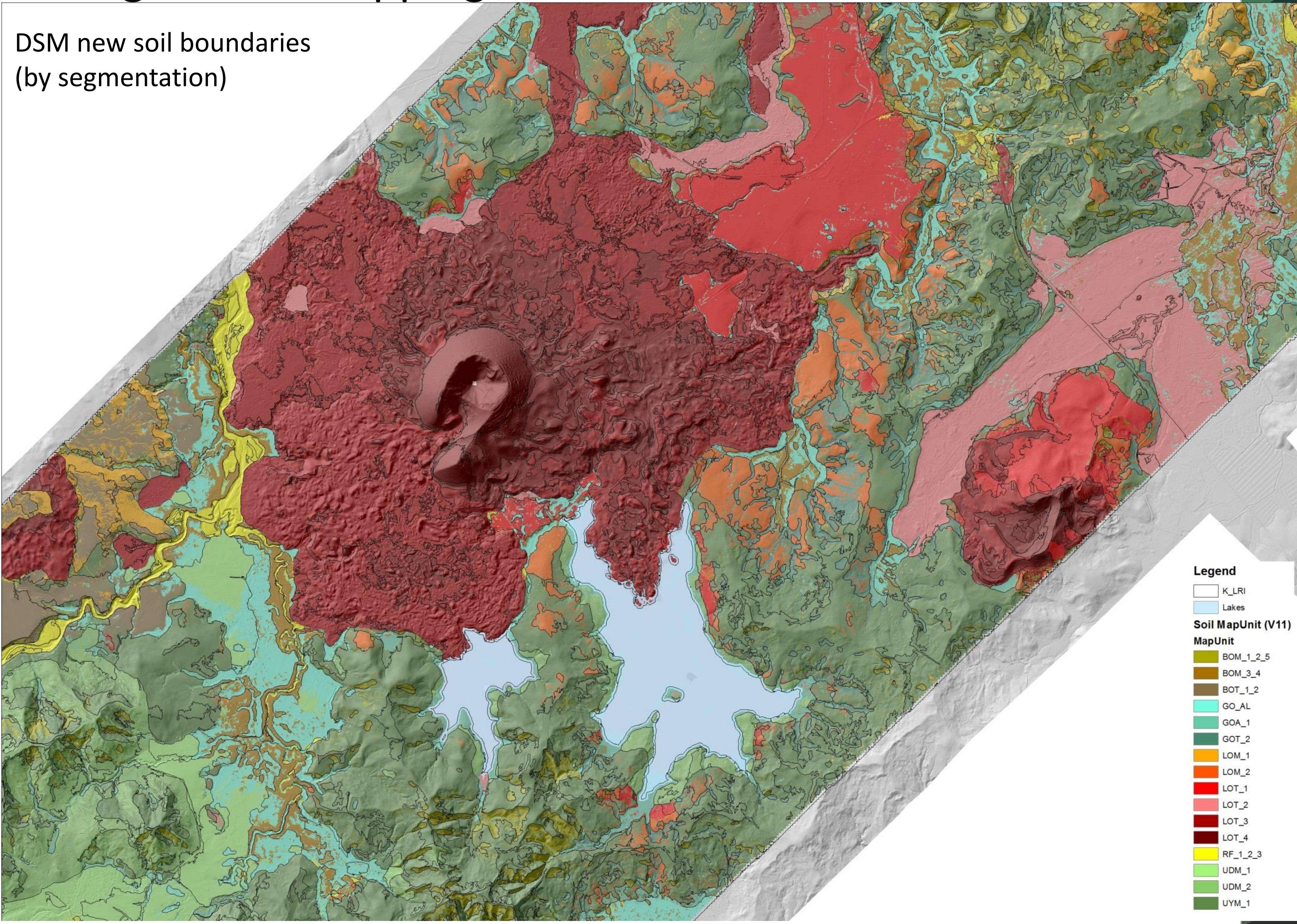
S = soil classes or attributes (to be modelled)

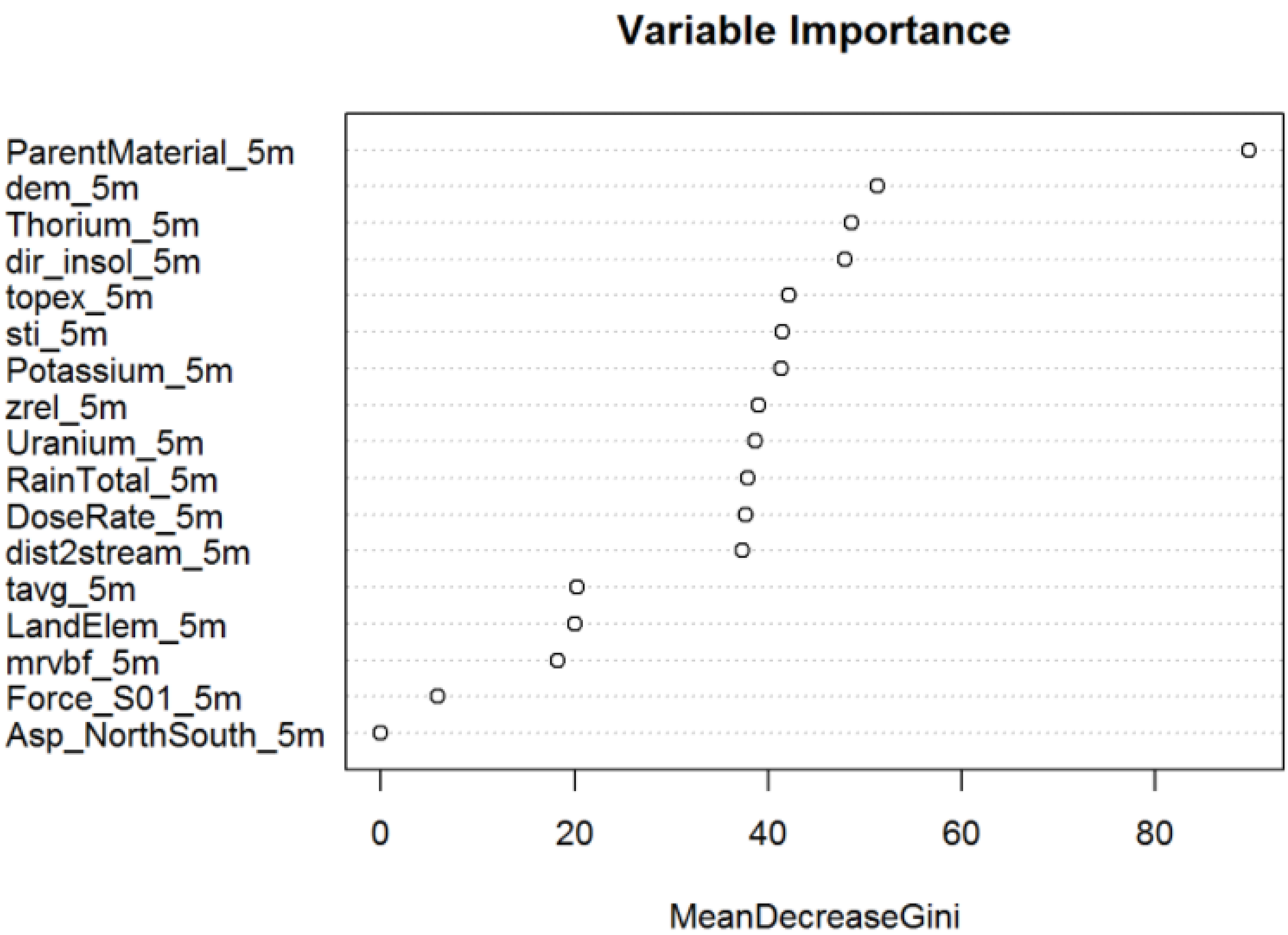
s = soil, measured properties of the soil at a point
c = climate, climatic properties at a point
o = organisms, land cover, vegetation, fauna, land use
r = relief, topography, landscape attributes
p = parent material, lithology
a = age, the time factor
n = spatial or geographic position

Decision Tree



Digital Soil Mapping – Random Forests





Relative importance of the different covariates used by random forests to predict soil class distribution.

Confusion Matrix

Mapunit	BOM_1_2_5	BOM_3_4	BOT_1_2	GO_AL	GOA_1	GOT_2	LOM_1	LOM_2	LOT_1	LOT_2	LOT_3	LOT_4	RF_1_2_3	UDM_1	UDM_2	UYM_1	Accuracy
BOM_1_2_5	28	1	0	3	0	0	6	0	1	0	0	0	0	0	4	14	0.49
BOM_3_4	0	33	0	10	0	0	1	0	0	3	0	0	8	1	0	0	0.59
BOT_1_2	0	1	10	2	0	0	1	0	1	1	0	0	0	1	0	0	0.59
GO_AL	1	12	0	38	0	0	1	0	0	1	0	0	2	4	0	4	0.60
GOA_1	0	0	0	0	8	1	0	0	0	0	0	0	0	0	8	4	0.38
GOT_2	0	0	0	3	0	5	0	2	0	0	0	0	0	0	0	4	0.36
LOM_1	3	3	0	1	0	0	36	2	0	0	0	0	0	0	0	9	0.67
LOM_2	2	0	0	1	0	1	3	10	0	0	0	0	0	0	0	19	0.28
LOT_1	0	1	1	0	0	1	0	1	10	0	3	2	0	0	0	5	0.42
LOT_2	0	2	1	1	0	0	1	0	1	20	4	1	0	0	0	0	0.65
LOT_3	1	1	0	0	0	0	0	0	3	1	42	3	0	0	0	1	0.81
LOT_4	0	0	0	0	0	0	0	0	0	0	5	26	0	0	0	0	0.84
RF_1_2_3	2	6	0	8	0	0	0	0	0	0	0	0	29	1	0	0	0.63
UDM_1	0	1	0	2	0	0	0	0	0	0	0	0	0	21	1	0	0.84
UDM_2	4	0	0	0	2	0	0	0	0	0	0	0	0	0	33	11	0.66
UYM_1	5	1	0	3	3	0	14	4	0	0	0	0	0	0	7	60	0.62
Reliability	0.61	0.53	0.83	0.53	0.62	0.63	0.57	0.53	0.63	0.77	0.78	0.81	0.74	0.75	0.62	0.46	0.61

The overall accuracy of the model is 61% and the Kappa Stat is 58%

Erosion Methodology

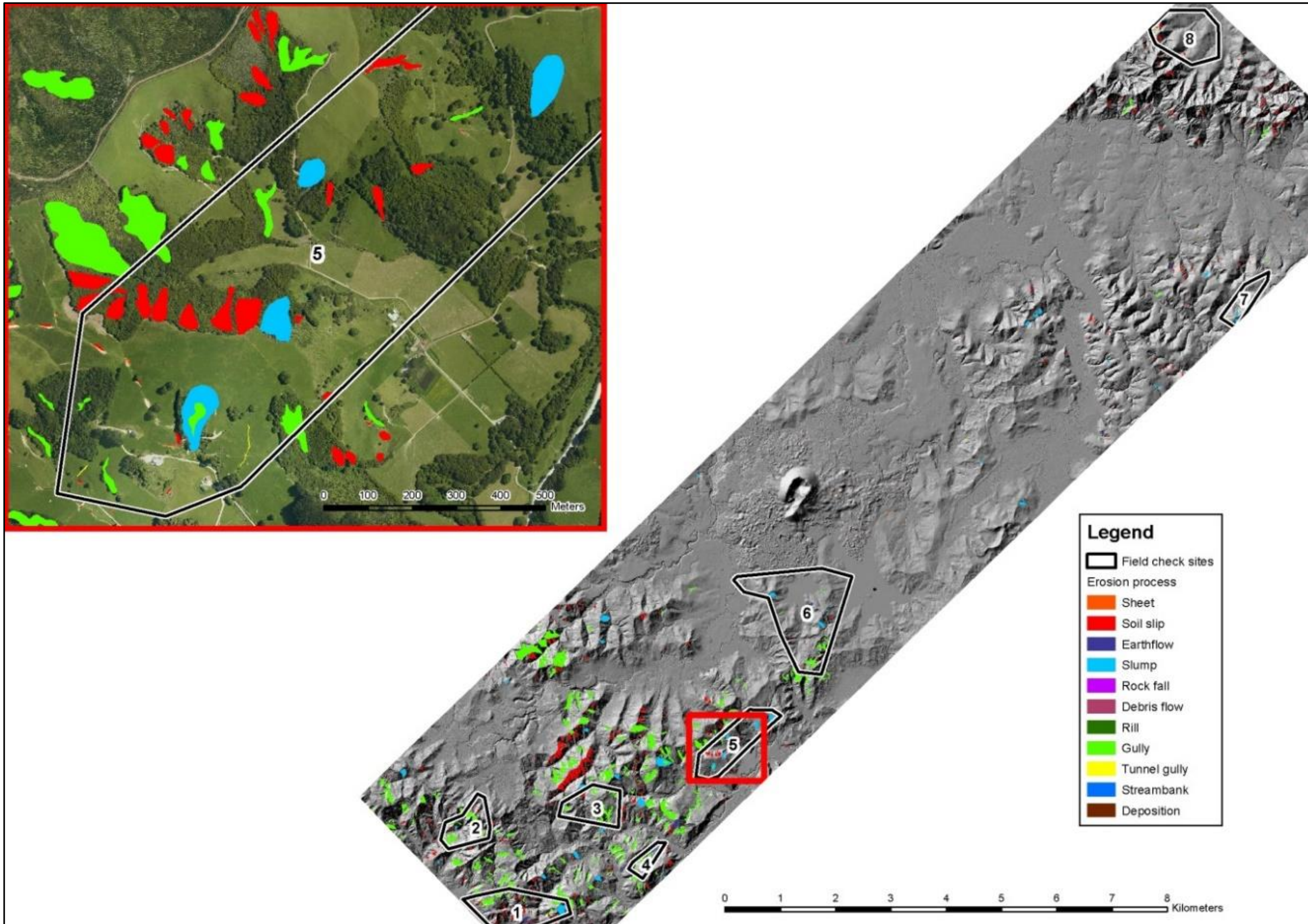
Aimed to provide the basis for:

- Traditional NZLRI erosion type and severity or
- An erosion susceptibility (ES) model that could be transferable

Recorded individual erosion features as opposed to the traditional approach of polygon-based erosion assessment.

Both present erosion (defined by the presence of bare ground) and past erosion (recognisable from morphology) were mapped as opposed to traditional NZLRI mapping where only present erosion is mapped.

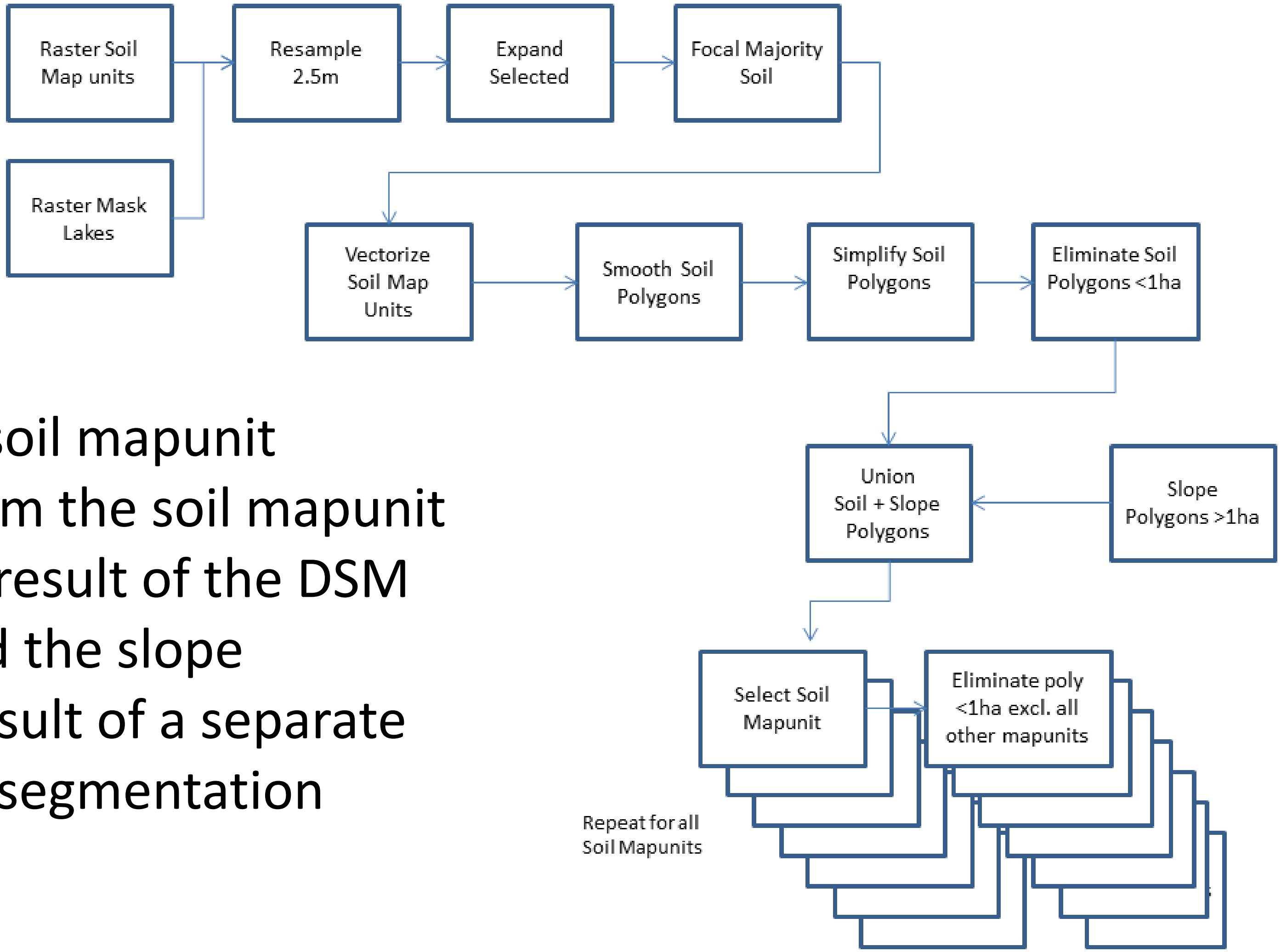
Erosion mapping – field check



Erosion Mapping - Results

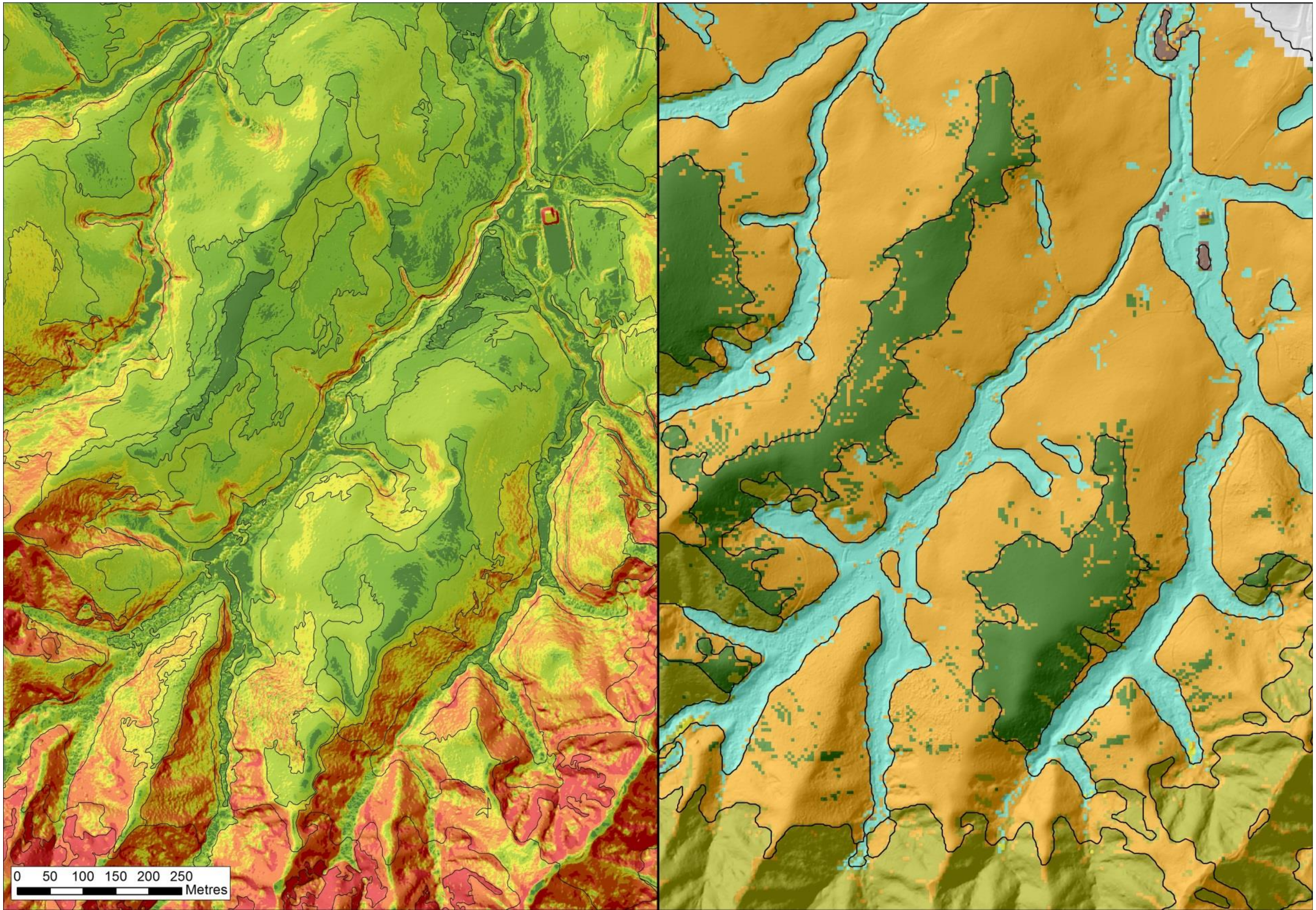
	Current		Recent		Historic		Total count	Total average area (m^2)
Erosion type	Count	Average area	Count	Average area	Count	Average area		
Soil slip	347	223	185	411	403	1089	935	633
Sheet	311	63					311	63
Gully	55	2887	55	6757	156	5595	266	5275
Slump	14	2216	9	4864	24	6289	47	4803
Streambank	43	66	1	38			44	65
Tunnel gully	30	133					30	133
Earthflow	7	1605	2	2744	9	3553	18	2705
Deposition	11	550	2	503			13	542
Debris flow	1	3998					1	3998
Rill	1	1142					1	1142
Rock fall	1	31					1	31
Total	821	385	254	1961	592	2525	1667	1385

Raster Inventory into Vector LUC SEGMENTATION



Generating soil mapunit polygons from the soil mapunit raster map (result of the DSM analysis) and the slope polygons (result of a separate slope raster segmentation process)

Segmentation results



Assigning attributes to polygons ZONAL HISTOGRAM

- Segmentation identifies zones (polygons) of broadly heterogeneous rock, soil and slope.
- **Zonal histogram** now delivers a summary of all of the raster values that occur within that relatively homogeneous area.
- This is an objective, repeatable and precise method for generating LRI-like attribute values for each polygon identified from underlying raster inventory.
- Rich data set – not just dominant values but full statistical breakdown
- Precise, but accuracy reliant on of raster inventory

RockCode	soilmapunit	A	B	C	D	E	F	G	LUCSLOPE
Af	BOM_1_2_5	9%	15%	43%	25%	7%	1%	0%	C+D
Vo	BOM_1_2_5	99%	0%	0%	0%	0%	0%	0%	A
Gw	BOM_1_2_5	98%	2%	0%	0%	0%	0%	0%	A
Ac	BOM_1_2_5	19%	20%	25%	29%	8%	0%	0%	D+C+B
Ac	BOM_1_2_5	13%	68%	19%	0%	0%	0%	0%	B
Ac	BOM_1_2_5	18%	34%	27%	9%	8%	4%	0%	B+C+A
Sm	BOM_1_2_5	3%	15%	63%	18%	1%	0%	0%	C
Ac+Sm	BOM_1_2_5	30%	60%	11%	0%	0%	0%	0%	B+A

LUC Legend

LUC Class	Reg. luc unit	Suite	Key characteristics										
			Rock (Pm)	soil (Order)	Slope	soil depth (cm)	TopStones	texture	perm	drainage	erosion	comments	Soil MU
2	2e1	6. young basalt	basaltic, or tephra /X	L, B (N, X)	A, A+B	md >45<100	<5%, 1 or 2	zl, fsl, plus	m, m/r	i to w	0; 1 R,W, Sh	fertile, what are the real diffs bt 2e1 & 2s1? MU LOT_1	MU LOT_1
new	2e1b	6. young basalt	basaltic Vo	BOT	A, A+B	d<100	<5%, 1 or 2	zl, fsl, plus	m, m/r	mw to i	0; 1 R,W, Sh	fertile, what are the real diffs bt 2e1 & 2s1? MU_BOT_1_2	companion LUC 2 for MU_BOT_1_2 Not Used
new	2e1c	6. young basalt? Tephric soils /Ultic paleosol on Gw OR Vu?	tephra /wGw OR Vu	LOM	A, A+B	md >45<100	<5%, 1 or 2	zl, fsl, plus	m, m/r	i to w	0; 1 R,W, Sh	fertile, what are the real diffs bt 2e1 & 2s1? MU LOM_1; MU LOM_2	companion luc 2s for MU LOM_1; MU LOM_2; Not Used
	2s1	6. young basalt	basaltic	L, (N, X)	A, A+B	md >45<100	<5%, 1 or 2	zl, fsl, plus	m, m/r, m/s	i to w	0; 1 R,W, Sh	fertile, MU LOM_1; MU LOM_2	LUC 2 for MU LOM_1; MU LOM_2?
new	2s1b	6. young basalt	basaltic, Vo	BOT	A, A+B	d>100	<5%, 1 or 2	zl, fsl, plus	m, m/r, m/s	mw to i	0; 1 R,W, Sh	fertile, BOT_1_2	BOT_1_2
	2w1	2a. alluvial low terraces	mixed Al, Af	R (B, N)	A, B	d, md, >45	<5%, 1 or 2	zl, fsl, cl?	m, m/s	i to mw	0-1 Sb, D; 1-2 Sb, D	Recent soils. I to MW drained. Flooding risk	companion luc 2 for MU_RT_1_2_3? MU BOM_3_4? Not used
	2w2	2b. alluvial low terraces with gley soils	mixed Al, Af	G	A (B)	d, md, >45	<5%, 1 or 2	zl, fsl, cl?	m, m/s	i	0; 0-1 Sb, D	Gley soils that can be drained. MU GO_al?	companion LUC 2 for MU GO_al? Not used
3	3e1	6. young basalt	basaltic	L, B (N, X)	B+C, C+B	s or d >20<45 (<100)	<35%, 1,2,or 3	zl, fsl, plus	m, m/r, m/s	i to w	0; 1Sh, R	fertile, erosion considered to be the major limitation; MU LOT_1	MU LOT_1
new	3e1b	6. young basalt? Tephric soils /Ultic paleosol on Gw	tephra /wGw	LOM	C	s or d >20<45 (<100)	<35%, 1,2,or 3	zl, fsl, plus	m, m/r, m/s	i to w	0; 1Sh, R	fertile, erosion considered to be the major limitation; MU LOM_1; MU LOM_2	MU LOM_1; MU LOM_2
	3e3	4a. Interbedded & massive sandstone & mudstone	Ac, Sm, Ac+Sm	Ultic	A, B	s >20<45	<5%, 1 or 2	zl, fsl, plus	m, m/r, m/s	i to w	0-1 Sh, R; 1-2 Sh, R	best of the Ultic soils	MU_UYM_1
	3s1	6. young basalt	basaltic	L (N, X)	A, B	s >20<45	<35%, 2,or 3	zl, fsl, cl?	m/r, r	w	0; 1W,Sh,R	fertile, shallow with surface stones, gravels and boulders	MU_LOT_2
new	3s1b	6. young basalt	basaltic, Vo	BOT	A, B	>100	<35%, 2,or 3	zl, fsl, cl?	m/r, r	mw	0; 1W,Sh,R	fertile, shallow with surface stones, gravels and boulders, BOT_1_2 How do you dT stoniness?	BOT_1_2
new	3s3a	3. Quaternary terraces	Gw + Us, Af	BOM	A, B, C	d>100; md >45<100	<5%, 1 or 2	zl, fsl, cl?	m, m/r, m/s	i to w	0; 1W, Sh, R	dissected terraces, foot slopes	MU 2 BOM_3_4
new	3w1a	2a. alluvial low terraces	mixed Al, Af	R (B, N)	A, B	d, md, s >20	<5%, 1 or 2	zl, fsl, cl?	m, m/s	i to mw	0-1 Sb, D; 1-2 Sb, D	Recent soils. I to MW drained. Flooding risk	MU_RT_1_2_3
new	3w1b	2a. alluvial low terraces	mixed Al, Af	BOM	A, B	d, md, s >20	<5%, 1 or 2	zl, fsl, cl?	m, m/s	i to mw	0-1 Sb, D; 1-2 Sb, D	BOM soils. I to MW drained. MU BOM_3_4. Flooding risk unable to be assessed, could be 2w.	MU BOM_3_4.
new	3w2	2b. alluvial floodplains & low terraces with gley soils	mixed Al, Af	G	A (B)	d, md, s >20	<5%, 1 or 2	zl, fsl, cl?	m, m/s	I	0-1 Sb, D; 1 Sb, D	Gley soils that can be drained. MU GO_al?	MU GO_al
new	4e2b	6. young basalt? Tephric soils /Ultic paleosol on Gw	tephra /wGw	LOM	D, E?	s or d >20<45 (<100)	<35%, 1,2,or 3	zl, fsl, plus	m, m/r, m/s	i to w	0; 1Sh, R	fertile, erosion considered to be the major limitation; MU LOM_1; MU LOM_2	MU LOM_1; MU LOM_2
part	4e6a	4b. Sed Rx, older shattered & sheared argillites & sandstone	Ar, Ms, Ss	UYM	C, B, (D)	d >100	<5%, 1 or 2	zl, cl	m/s	I to p	1Sh, G, T, Ss; 2 Sh, G, T, Ss	downlands - whats the diff Bt 4e6, 4e7, 4e8?	MU UYM_1 on Ar, Sm
part	4e6b	4b. Sed Rx, older shattered & sheared argillites & sandstone	Ar, Ms, Ss	Brown	C, B, (D)	d >100	<5%, 1 or 2	zl, cl	m/s	I to p	1Sh, G, T, Ss; 2 Sh, G, T, Ss	downlands - differences bt N4e6, 4e7, 4e8 are not clear	MU_BOM_1_2_5
part	4e7a	5. Greywacke terrain	Gw	UYM, UYT	C, B, (D)	d >100	<5%, 1 or 2	zl, cl	m/s	I to p	0-1ShG, T, Ss; 2 Sh, G, T,	downlands - whats the diff Bt 4e6, 4e7, 4e8?	MU UYM_1 on Gw
part	4e7b	5. Greywacke terrain	wGw, Gw	BOM	C, D, B, (A)	d >100	<5%, 1 or 2	zl, cl	m/s	I to p	0-1ShG, T, Ss; 2 Sh, G, T,	downlands - differences bt N4e6, 4e7, 4e8 are not clear	MU BOM_1_2_5 on Gw
	4e12a	4g. Podzols on sedimentary rocks, UDM on Ac	Ac	UDM	A, B	d >100	<5%, 1 or 2	zl, cl	m/s	I or p	1-2Sh, T; 2Ef, Ss, T	undulating arable component	MU_UDM_2 (A+B slopes)
	4s1	6. young basalt	basaltic	L, B (N, X)	A, B, C	vs, s >10<45	>5>35%, 2, 3, 4	zl, fsl, cl?	m/r, r	w	0-1; 2Sh, 1W,Sh,R	fertile, shallow with surface stones, gravels and boulders	MU_LOT_2
new	4s4_a	4g. Podzols on sedimentary rocks. UDM on terraces	mixed Al, Af	UDM	B, A (C)	d >100	<5%, 1 or 2	zl, cl	m/s	p to i	0--1 Sh; 1-2Sh, G	split into terrace 4s4_a and downland 4s4_b luc units; MU UDM_1	MU UDM_1, deep component
split a	4w1a	2c. poorly drained floodplains and low terraces	mixed Al, Af, Af+Pt	R	A, B, C	d, md, s >20	<5%, 1 or 2	zl, fsl, cl?	m, m/s	I to p	0-2 Sb, D; 2 Sb, D	mixed soils with wetness limitation, more like original description	MU_RT_1_2_3
split b	4w1b	2b? alluvial floodplains & low terraces with gley soils	mixed Al, Af, Af+Pt	GO?	A, B	d, md, s >20	<5%, 1 or 2	zl, fsl, cl?	m, m/s	p	0-2 Sb, D; 2 Sb, D	Gley soils that can be drained. GO_al?	GO_al
	New 4w5	Gley soils associated with tephric LOM, BOM soils on hills	Ac+Sm, Gw, Vu	GOT	C, B, A	d>100	<5%, 1 or 3	zl, fsl, cl?	m, m/s	i	0	GOT_1	GOT_1
5	5s1	6. young basalt	basaltic	LOT, X, B	A, B, C	vs, s >10<45	>35%, 4	zl, fsl, cl?	m/r, r	w (i)	0; 1-2Sh	bouldery soils, drainage may be impeded by underlying basalt. HIGHLY PRODUCTIVE???	MU_LOT_3
6	6e4	6. young basalt	basaltic	L, X, B	D, D+E, E, F	vs, s >10<45	>35%, 4	zl, fsl, cl?	m/r, r	w (i)	0-1; 1-2Ss, Sh	bouldery soils, steep slopes	LOT_4
	6e4b	6. young basalt? tephric /Ultic paleosol on Gw	tephra /wGw	LOM	F, E	s or d >20<45 (<100)	<35%, 1,2,or 3	zl, fsl, plus	m, m/r, m/s	i to w	0-1; 1-2Ss, Sh	steep slopes. MU LOM_1	LOM_1
part	6e7a	4b. Sed Rx, older shattered & sheared argillites & sandstone	Ar, Ms, Ss	UXX, UYM	F, D, E	d >100	<5%, 1 or 2	zl, cl	m/s	I to p	1-2Sh, Ss, Ef, T; 2Ef, G, Ss, T, 3 Sh	Hill country - whats the diff Bt 6e7 and 9, 17, 19?	MU UYM_1 on Ar, Sm
part	6e7b	4b. Sed Rx, older shattered & sheared argillites & sandstone	Ar, Ms, Ss	BOM	F, D, E	d >100	<5%, 1 or 2	zl, cl	m/s	I to p	1-2Sh, Ss, Ef, T; 2Ef, G, Ss, T, 3 Sh	Hill country - whats the diff Bt 6e7 and 9, 17, 19?	MU BOM_1_2_5 on Ar, Sm, and ?Vu?
part	6e9a	5. Greywacke terrain	wGw, Gw	UYM, UYT	E, E+D	d>100	<5%, 1 or 2	zl, cl	m/s	i	1-2Ss, Sh, G, Es; 2 Ss, E, Sh, G	not as steep as 6e17, Ultic soils	MU UYM_1 on Gw, easier slopes
part	6e9b	5. Greywacke terrain	wGw, Gw	BOM	E, E+D	d>100	<5%, 1 or 2	zl, cl	m/s	i	1-2Ss, Sh, G, Es; 2 Ss, E, Sh, G	not as steep as 6e17, Brown soils	MU BOM_1_2_5 on Gw, easier slopes
part	6e17a	5. Greywacke terrain	wGw, Gw	UYM, UYT	E+F, F	d>100	<5%, 1 or 2	zl, cl	m/s	i	1-2Ss, Sh, G; 2 Ss, Sh, G	steeper than 6e9	MU UYM_1 on Gw, steeper slopes
part	6e17b	5. Greywacke terrain	wGw, Gw	BOM	F, F+E	d>100	<5%, 1 or 2	zl, cl	m/s	i	1-2Ss, Sh, G; 2 Ss, Sh, G	steeper than 6e9b, MU BOM_1_2_5 steep hill	MU BOM_1_2_5 steep hills on Gw
part	6e19a	4d. Crushed argillite. UDM on Ac	Ac	UDM_2	C, D, E	d or vs	<5%, 1 or 2	zl, cl	m/s	I to p	1-3 G, Sh, Ss; 3G, Sh, Ss	C to E slopes	MU_UDM_2 (>B <F slopes)
new	6e20	4d. Crushed argillite	Ac	BOM	F, G	d or vs	<5%, 1 or 2	zl, cl	m/s	I to p	1-3 G, Sh, Ss; 3G, Sh, Ss	F, G slopes	MU_BOM_1_2_5
	6s1	6. young basalt	basaltic	LOT, X, B	A, B, C, D, E	vs, s >10<45	>35%, 4	zl, fsl, cl?	m/r, r	w (i)	0-1Sh; 1Sh	bouldery soils, drainage may be impeded by underlying basalt	MU_LOT_3; MU_LOT_4
new	6s5_b	4g. Podzols on sedimentary rocks? UDM on terraces	mixed Al, Af	UDM	B, A (C)	vs <20	<5%, 1 or 2	zl, cl	m/s	p	0--1 Sh; 1-2Sh, G	split into terrace 6s5_b and downland 6s5_a luc units; MU_UDM_1	MU_UDM_1 v shallow component
	6w1a	2c. poorly drained floodplains and alluvial low terraces	mixed Al, Af	R, (B),	A	d, md, s >20	<5%, 1 or 2	zl, fsl, cl?	m/s, s	p	0-2Sb, D; 0-2 Sb, D2-3Sb	frequent flooding OR permaently high WT	LUC 6w for MU_RF_1_2_3
new	6w1b	2b? poorly drained floodplains and alluvial low terraces	mixed Al, Af, Af+Pt	GO?	A, B	d, md, s >20	<5%, 1 or 2	zl, fsl, cl?	m/s, s	p	0-2Sb, D; 0-2 Sb, D2-3Sb	frequent flooding OR permaently high WT. LUC 6 on flood risk	GO_al
new	New 6w4	Acid Gley soils associated with Ultic hill soils	Ar or Ac+Sm	GOA	B, A, C	d >100	<5%, 1 or 2	zl, fsl, cl?	m/s, s	p	0	UYM + GOA_1?	GOA_1
new	New 6w5	Gley soils associated with tephric LOM, BOM soils on hills	Ac+Sm, Gw, Vu	GOT	C, B, A	d >100	<5%, 1 or 2	zl, fsl, cl?	m/s, s	p	0	GOT_1	GOT_1
7	7e8	4d. Crushed argillite. UDM on Ac	Ac	UDM	F	d or vs	<5%, 1 or 2	zl, cl	m/s	I to p	1-3 G, Sh, Ss; 5G, 4Sh, Ss	F slopes	MU_UDM_2 (>E slopes)
new	7s1	6. young basalt	basaltic	LOT	C, A, B	vs, s >10<45	>70%, 4	zl, fsl, cl?	m/r, r	w	0-1; 2Sh, 1W,Sh,R	fertile, shallow with surface stones, gravels and boulders	MU_LOT_3

LUC Legend

LUC Unit 4e7b

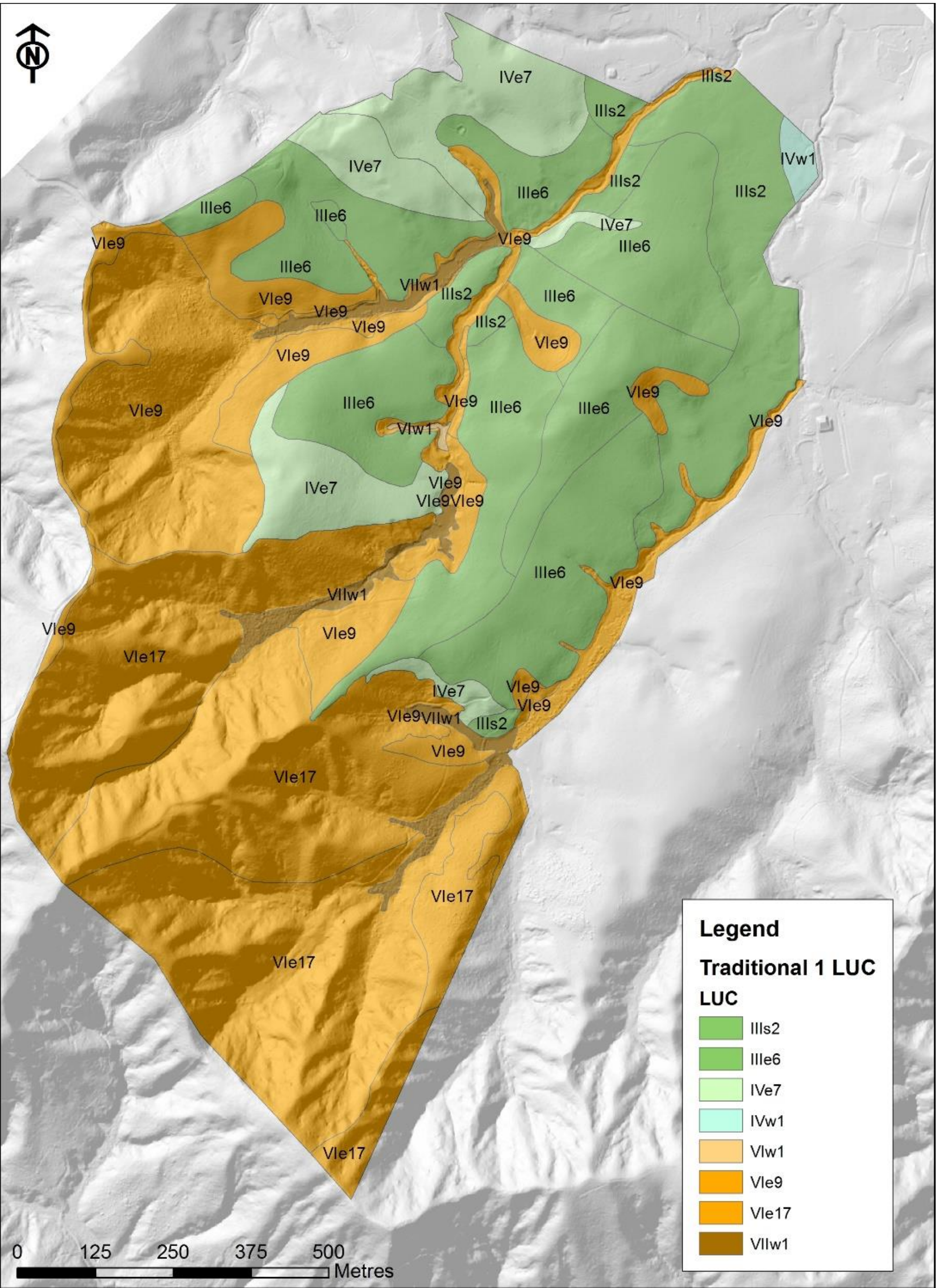
“rolling to strongly rolling downlands on weathered greywacke with deep imperfectly to moderately well drained Mottled Orthic Brown soils which have a potential for moderate to severe sheet, rill and gully erosion when cultivated”.

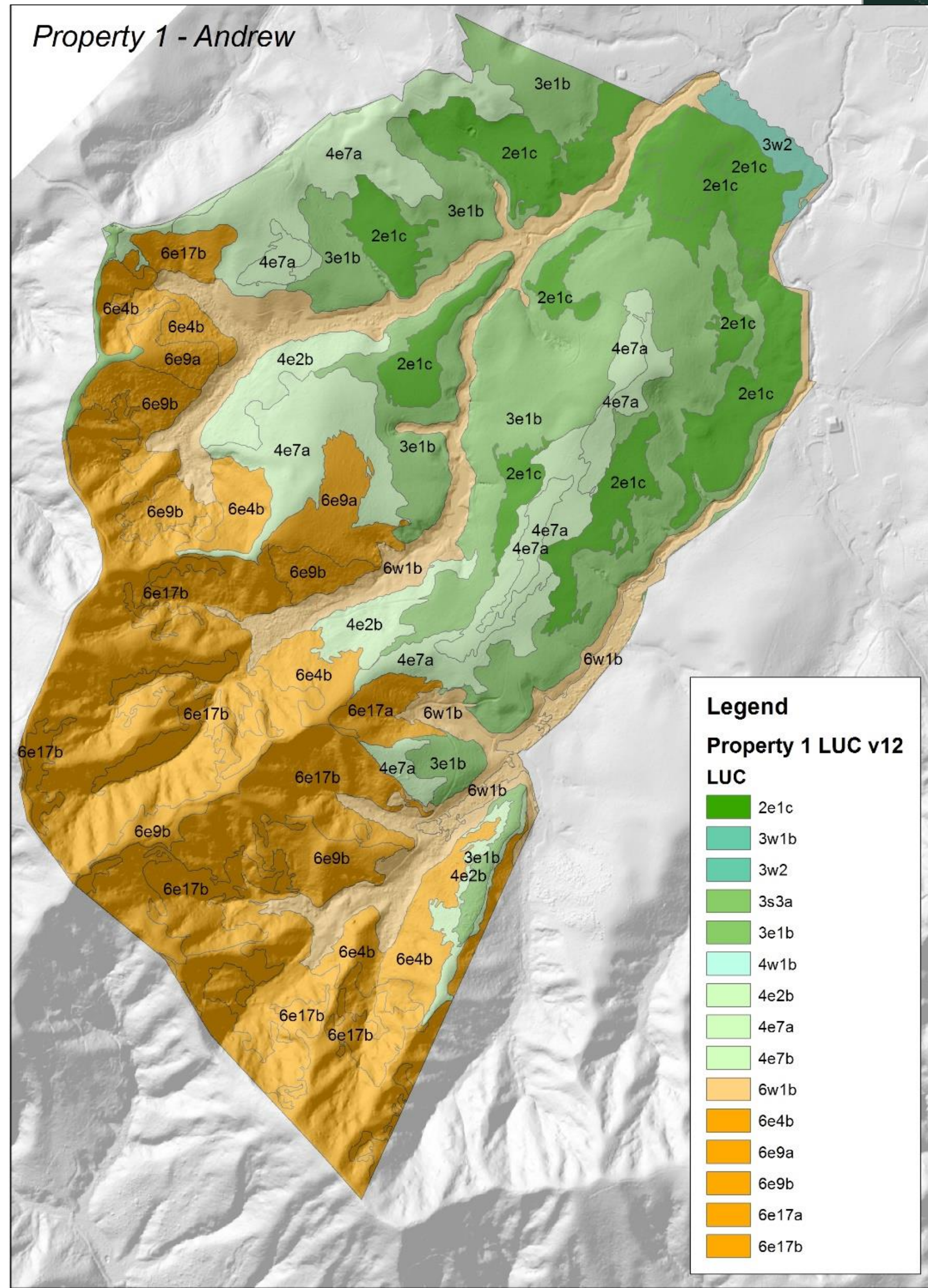
This description is turned into an IF>THEN rule.

IF Rock = wGw or wGw+Us AND Slope <E AND Soil = BOM_1_2_5, AND Drainage = imperfectly to moderately well drained (i or mw) [any drainage] AND Depth = deep [any depth] THEN LUC = 4e7b

All rules are coded into a series of sequential SELECT and CALCULATE functions which find all inventory polygons that match the rule specification and assign the LUC code accordingly.

Comparison 1

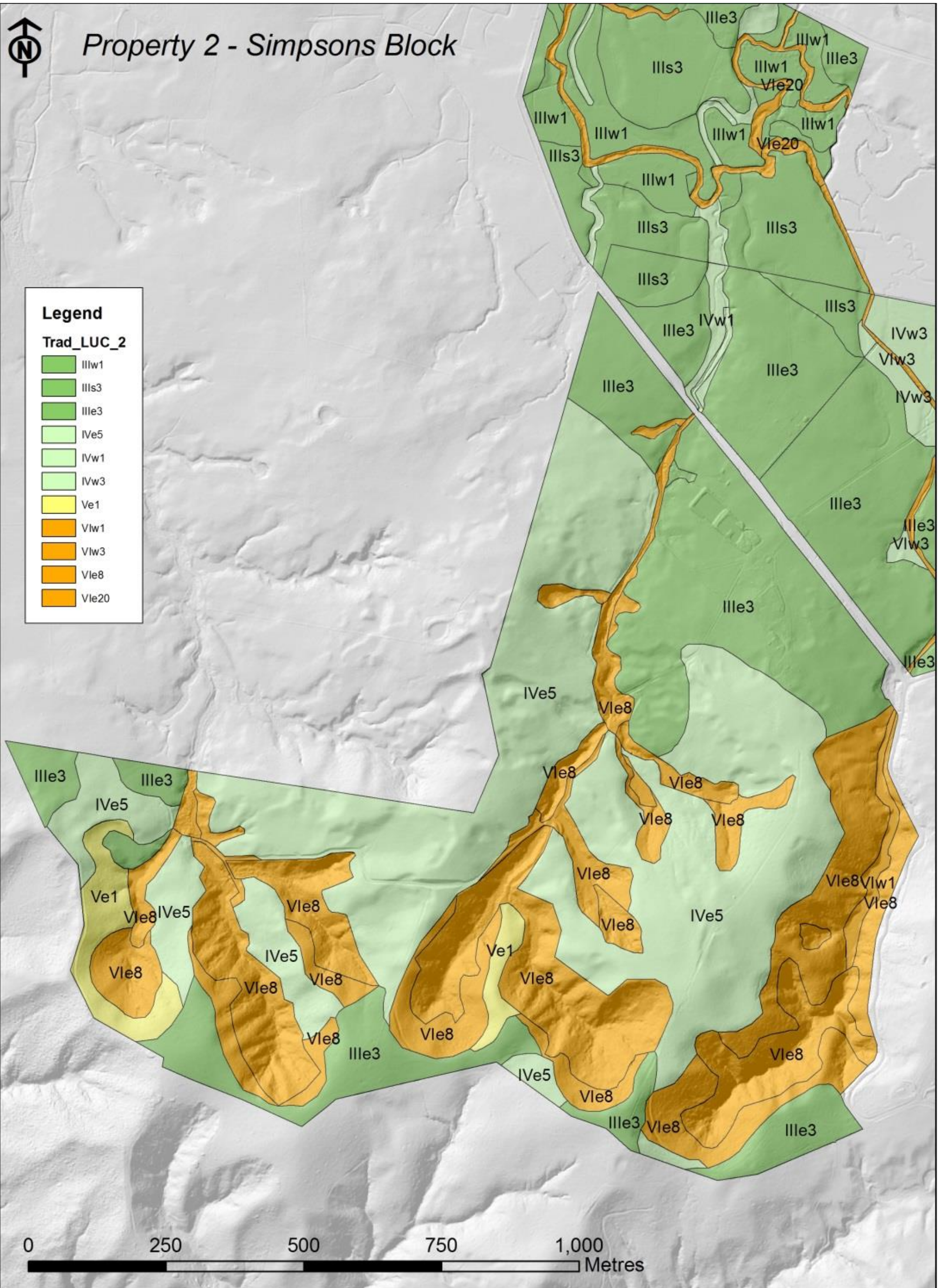


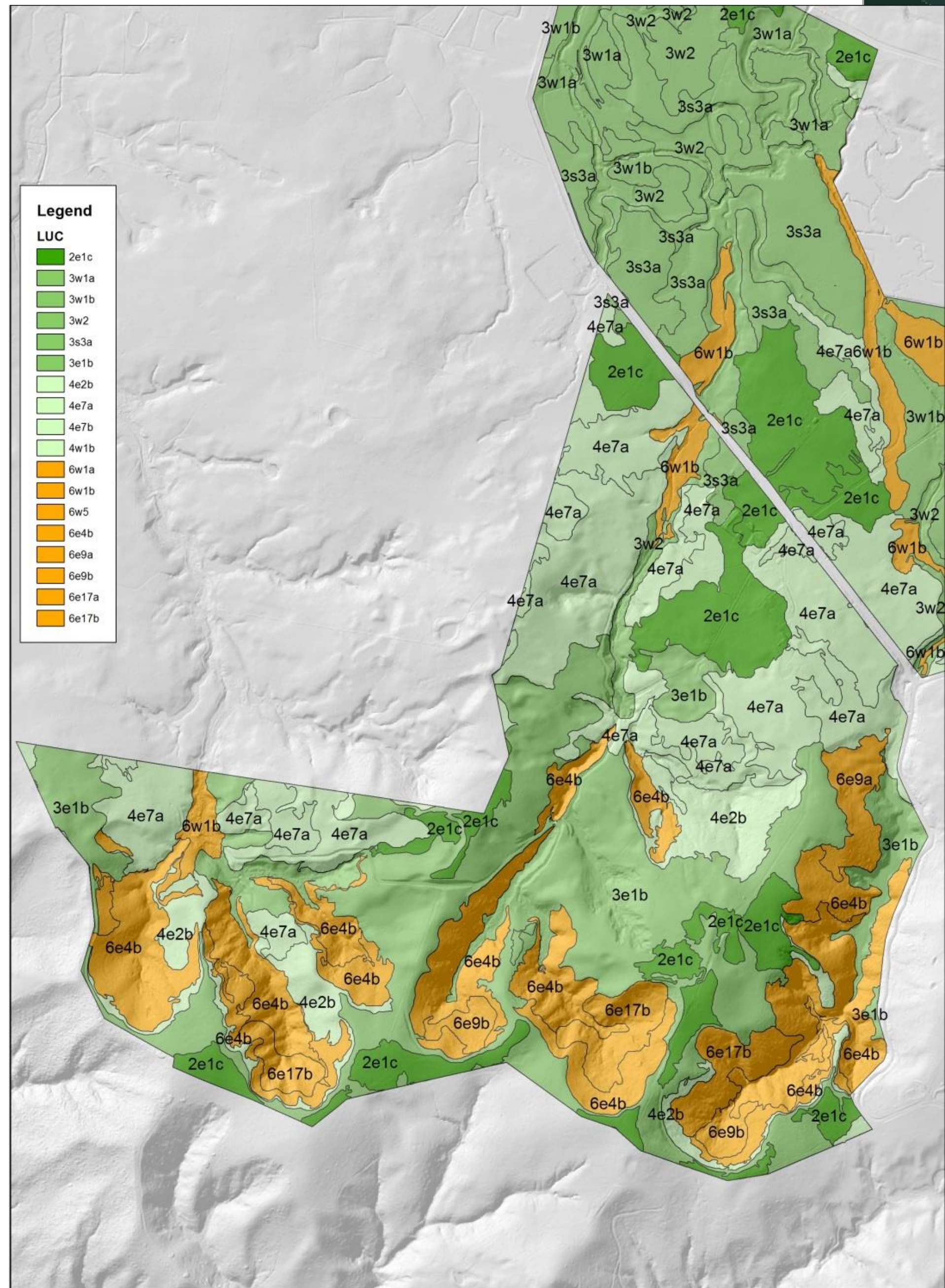


Comments property 1

	Landcare Research	LandVision
Geology / rock type	Very similar depiction by both parties, greywacke and alluvium.	Used the weathered symbol Gw', and Us+Gw
Soils	Significant differences; • Identified Allophanic soils [LOM] on the lower slopes of the property and the presence of tephra • Brown soils on the steeper component. • Preserving the gully floor Gley soil component has led to it being exaggerated.	• Mapped Marua soils, an Ultic soil [UYM] on lower slopes and a new LV defined unit 3e6 that does not mention a tephra component. • Mapped as Rangiora soils an Ultic soil [UEM] • Areas of Gley soils and peat are very precisely mapped
Slope	Mixed, LCR has more detail whereas LV under estimated both easy and steeper slopes • C+B • F+E	• B+C • E+F
LUC	Mixed; • 2e1c [LOM soils] • 4e7a, 3e1b • 6e9 & 6e17, more detail • 4e7, 4e2 • 6e17b, 6e9 • 6w1b- valley floors maybe exaggerated • 3e1b (+4e7a) LR recognise the presence of tephra [LOM soils] and 2e1c on B+A slopes	• 3e6, new LV defined unit that does not mention a tephra component which is assigned an Ultic soil • 4e7, 3e6 new • 6e9 • 3e6, 4e7 • 6e17 • 7w1 • Used a new LV 3e6 on Ultic soils, which is questionable
Summary comment	Variability centres largely on the recognition or not of the tephra component, and the follow on effect this has on soil properties and classification, and on LUC class assignment.	

Comparison 2





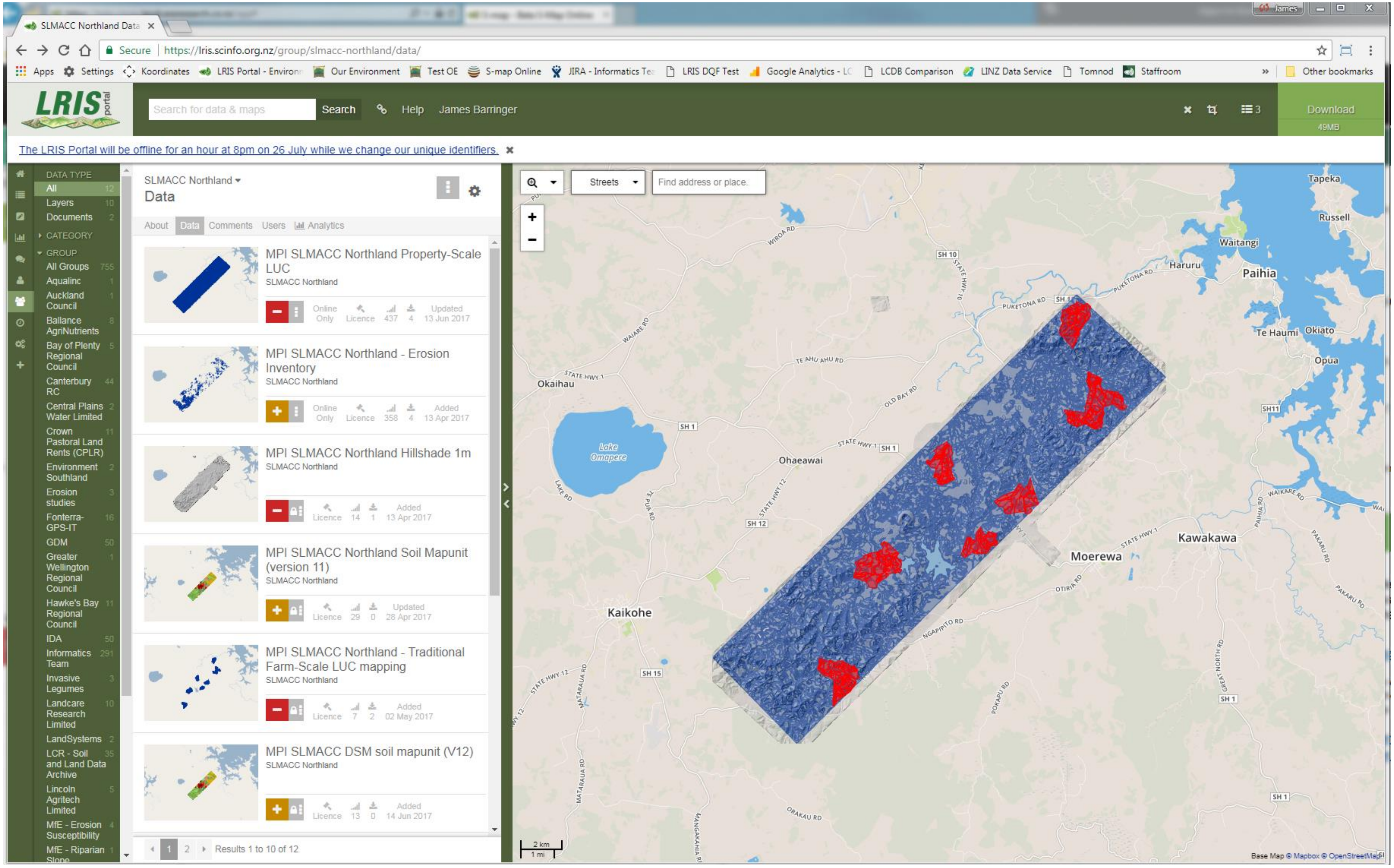
Comments Property 2

	Landcare Research	LandVision Limited
Geology / rock type	Significant differences; Simple depiction - alluvium, unconsolidated sands and gravels over greywacke, and greywacke on valley fill, downlands and hill country respectively. <u>No loess</u> mapped. The extensive presence of tephra is indicated by the mapping of Mottled Orthic Allophanic Soils.	Multiple rock types depicted 6 variations and combinations of alluvium mapped, a significant and patchy loess cover on massive sandstone and mudstone mapped extensively.
Soils	• Recognise a significant tephra component LOM Soils on the hills and footslopes • Northern high terrace mapped as GO-al (data point) • Southern high terrace-footslope; GO_al +BOM_3_4, GO_al component enlarged, maybe BOM dominated • North eastern valley fill, Recent and Brown Soils • High terrace/footslope either side of McIntyre Road, LOM_1	• Mapped as Marua soils, an Ultic soil [UYM]. These soils have good physical properties not associated with Ultic Soils. No mention of tephra a component. [NB the farmer knows these soils as Marua!] • Mapped as Rangiora soils [UEM] • Mapped as Rangiora soils [UEM], most unlikely, more like BOM/LOT with GOT • Gley and Organic Soils [highly variable fluvial system] • Mapped as Rangiora soils [UEM]
Slope	LCR generally more detailed/precise	Some subtle channel features mapped, both under and overestimated both easy and steeper slopes
LUC	Mixed; reflects variation in soil interpretation • 2e1c (LOM_1) • Gullies, 6e17b, 6e4b • Rounded spurs & shoulder slopes 2e1c • 4e7, 3e1b • 3w2, 3s3a • 3w2, 2e1c • 3w1a, 3w1b • 2e1c	• 3e3 for Ultic soil? • 6e8 • 6e9 • 3e3 • 4e5 • 3s3 • 3e3 • 4w3 • 3e3 [on Marua UYM unlikely!]
Summary comment	Variability centres largely on geology and the failure to recognise the tephra component (mistaken as loess?), and the follow on effect this has on soil properties and classification (the presence of Allophanic and/or Brown Soils), on LUC class assignment.	

Costs

	Hectares	Travel + Expenses	Field Work	Office	Total (plus OH)
Traditional	1,084	$3,330	$3,840	$1,920	$9090
Digital (Research)	10,000				$500,000
LiDAR		$35,000		$ 5,000	
Vehicles		$25,000			
Soil Survey/Rock			$60,000	$25,000	
DSM Analysis				$25,000	
Erosion			$11,500	$15,000	
Forest Index		$40,000			
LUC Legend				$20,000	
Auto Mapping				$15,000	
Reporting				$15,000	$483,000
Digital (Operat.)	10,000				
LiDAR		$35,000		$10,000	
Vehicles		$15,000			
Soil Survey/Rock			$50,000	$25,000	
DSM Analysis				$ 5,000	
Erosion			$11,500	$12,000	
Forest Index		??			
LUC Legend				$ 2,000	
Auto Mapping				$ 5,000	
Reporting				$ 5,000	$297,000

Data on LRIS Portal



Did we achieve our objectives

Did the project deliver accurate inventory layers at farm-scale?

A qualified yes - strengths and weakness – Scale/Cost – Precision/Accuracy – All rounders/Experts – Farm Enterprise orientation

Did the project deliver LUC maps that are fit for purpose?

A qualified yes - both maps would be a substantial improvement over the regional dataset for farm management but more work required to get land user feedback.

Could digital methods reduce the overall cost per hectare of LUC mapping?

No – at least not at individual farm-scale but economy of scale, expertise and charge out/overhead factors suggest the differential could be markedly reduced once operational.

Are digital LUC mapping procedures more quantitative/less subjective?

Yes! – but still some areas to improve on (e.g., sampling and map unit definition)

Are digital LUC mapping procedures more repeatable?

Yes! – a quantum advance in repeatability of mapping.

Would remapping of LUC be less costly using digital methods?

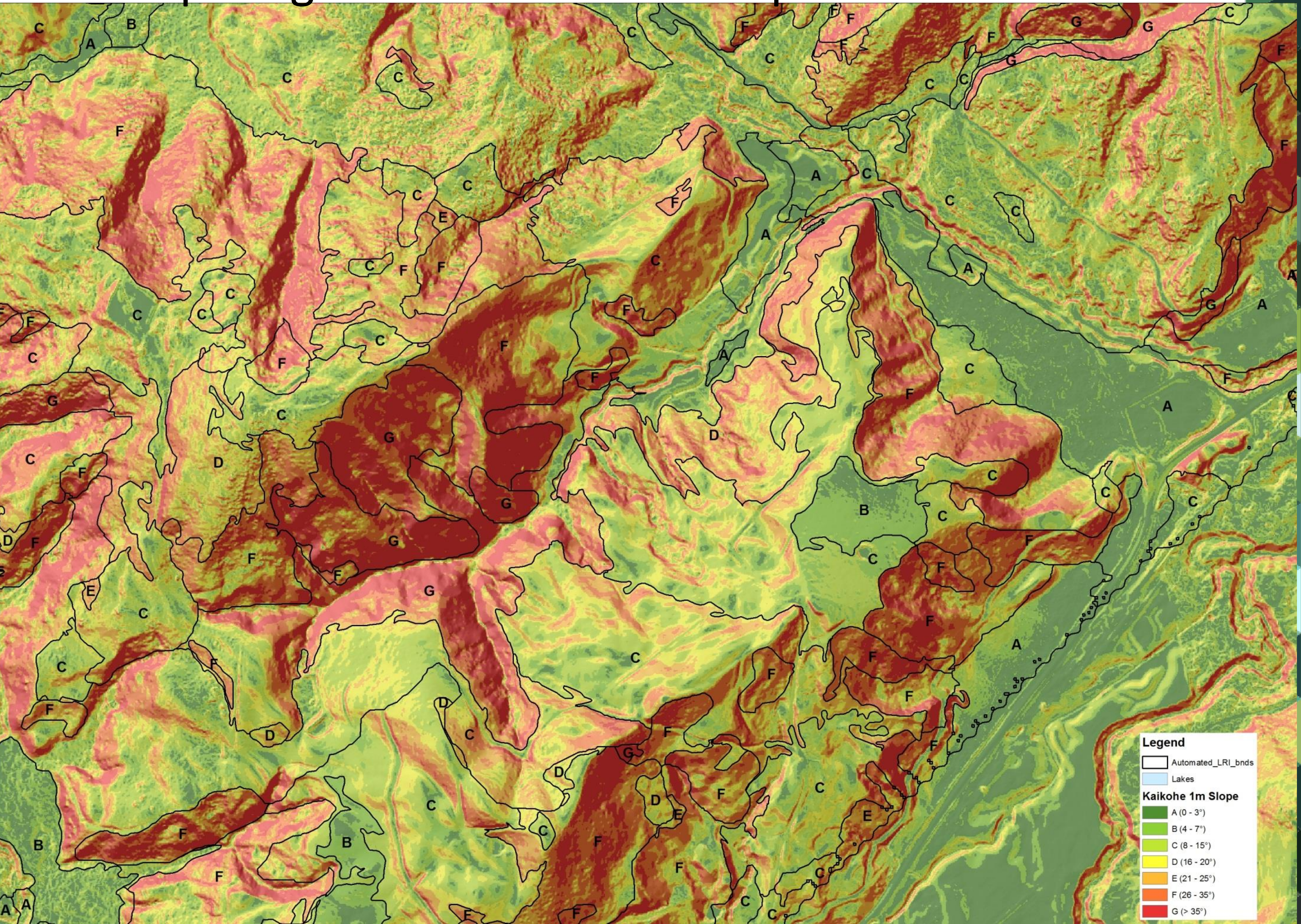
Yes – ability to re-use and/or add to previous data collection and re-run processs

Was a method established for comparing traditional and digital map products?

Qualified Yes – using statistical analyses to compare the two mapping approaches was not particularly successful. A subjective visual assessment gave the most effective assessment of the two mapping techniques in this case.

Questions

Comparing DEM and Manual Slopes

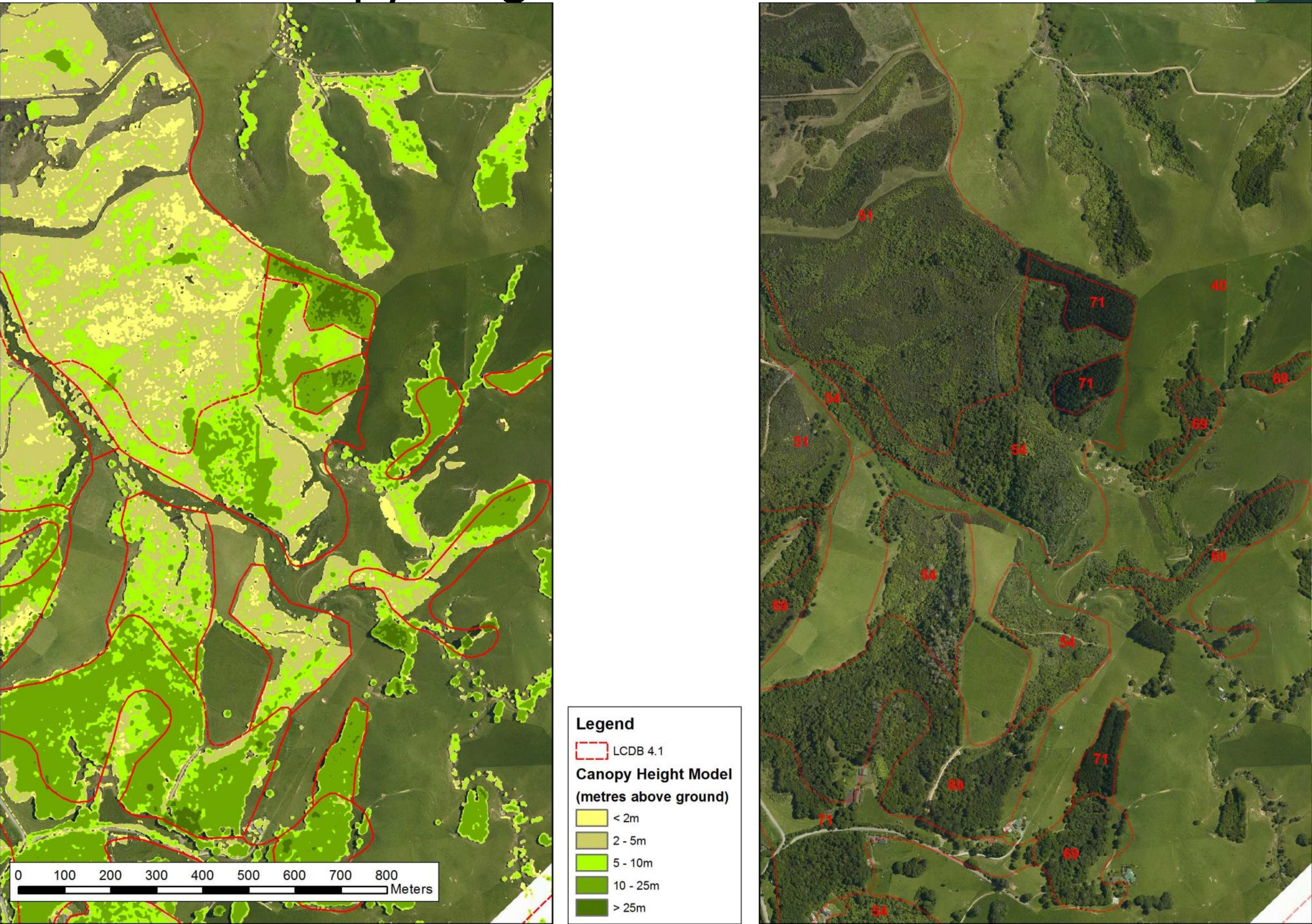


Conclusions

- The LUC maps produced by both methods are broadly comparable but contain many differences in detail (both spatial and attribute).
- Both approaches have strengths and weaknesses
- Discussion focussed on inventory factors, detail of mapping, interpretations of soil, slope, erosion and LUC assignment.
- The segmentation/zonal histogram methodology works well, and is mostly constrained by the quality of the inventory data.
- better documentation of field data , covariate data, and models, and ease of use of improved inventory layers at much lower marginal costs than remapping
  = opportunity for rapid update
  = advance in repeatability and efficiency of LUC mapping.

LiDAR with simultaneous Orthophoto

LiDAR Canopy Height Model vs LCDB4



Examples of CHM in Northland