Landcare Research
Manaaki Whenua

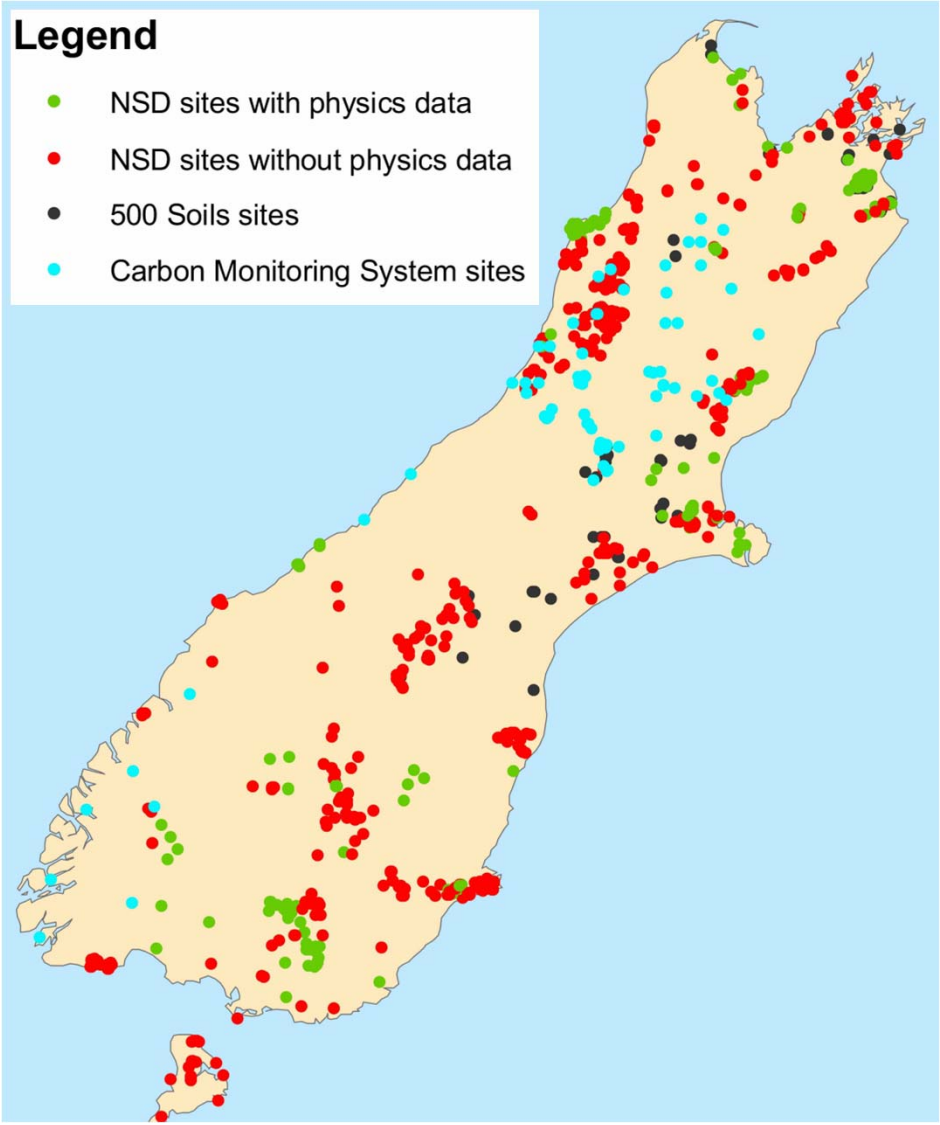
NZ soil data

Manaaki Whenua - Landcare Research

- National Soils Database
- Land Resource Information
- Fundamental Soil Layers
- S-map
- Additional soil property maps

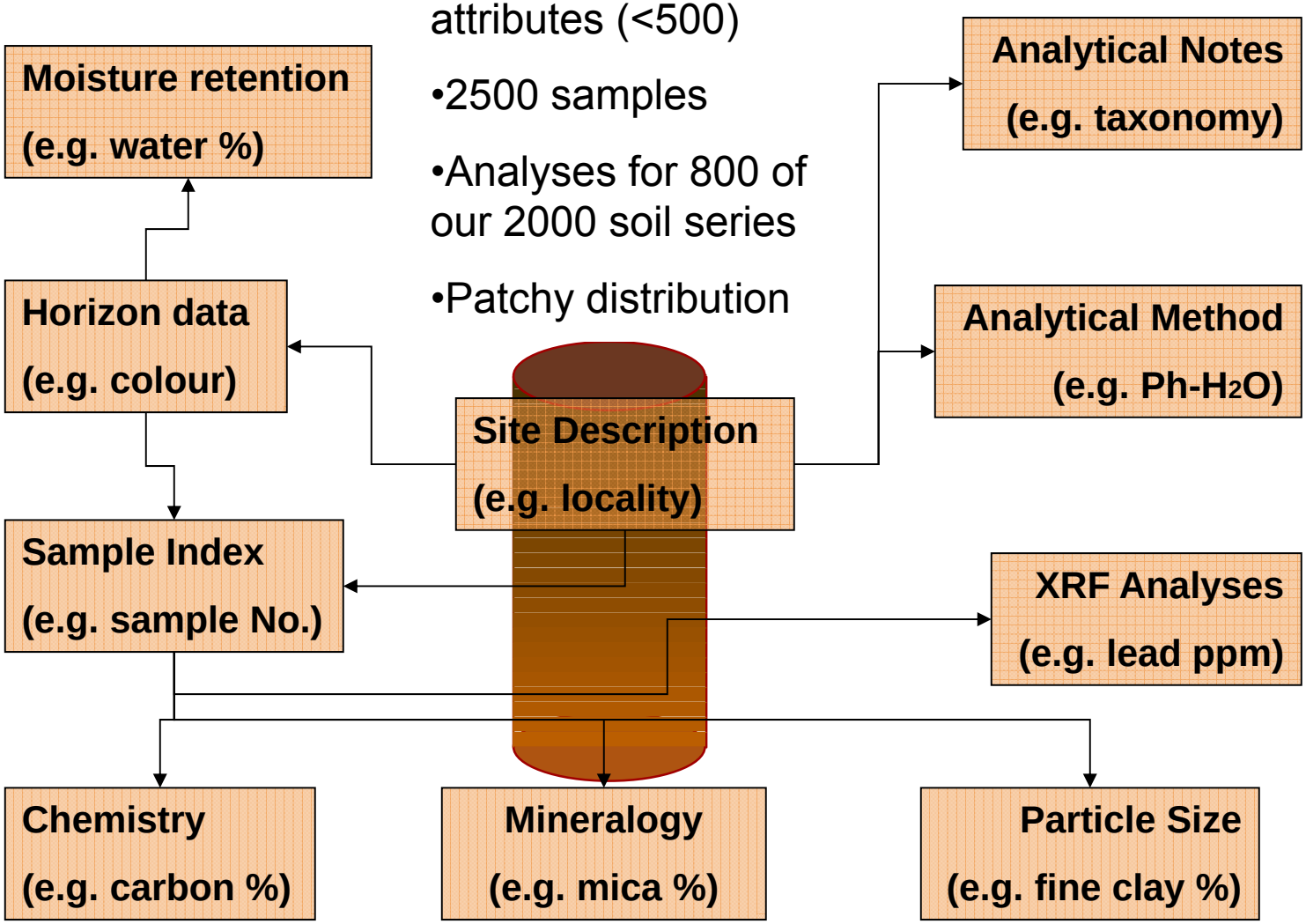
NZ NSD Distribution

NSD site distribution and data content is influenced by former soil surveys and requirements of projects



NZ National Soils Database

- Point – multiple attributes (<500)
- 2500 samples
- Analyses for 800 of our 2000 soil series
- Patchy distribution



NZ Land Resource Inventory

Physiographic units

Single polygon set – multiple attributes

1st Ed 1973-79

1:63,360 scale

90,000 polygons

MMU 40ha

Digital / 320 maps

Rock type

Surface rock

Underlying rock

Soil code

Soil survey

Rock - Soil - Slope
Erosion - Vegetation

LUC

2nd Ed 1982-98 (20%)

1:50,000 scale

100,000 polygons

MMU 10ha

Digital

LUC Unit

Potential erosion

P radiata site index

Stock Carrying Capacity

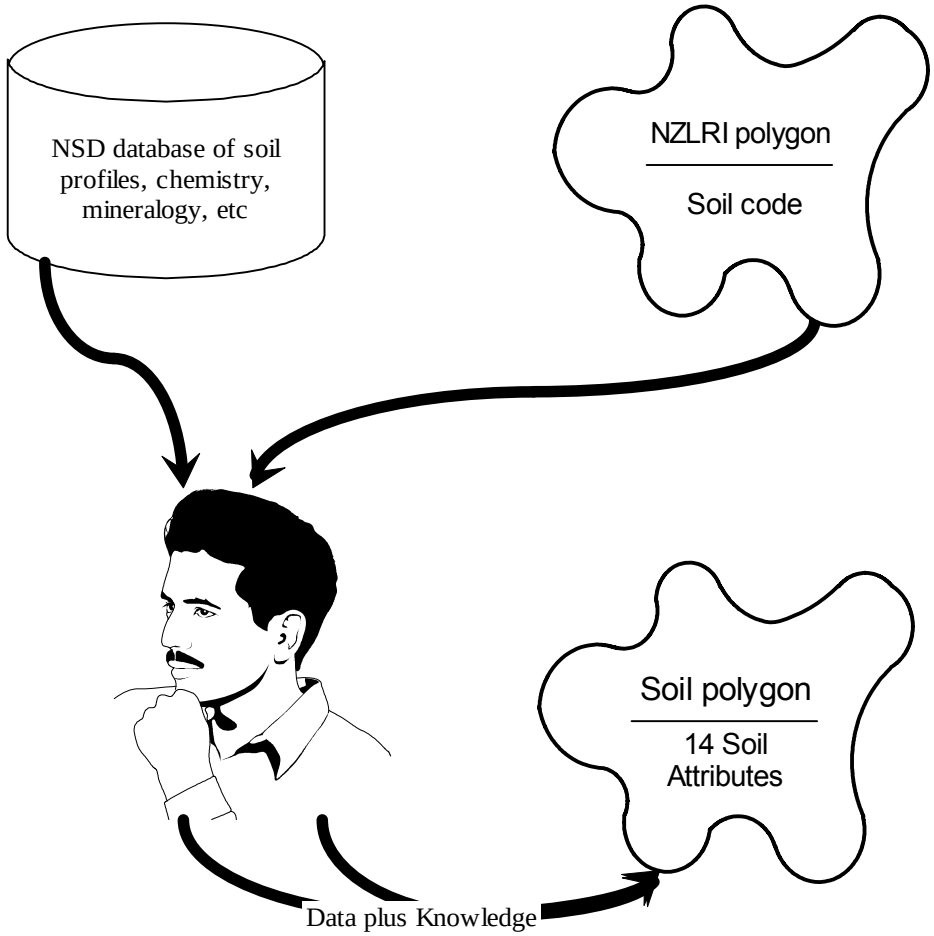
NZ Land Resource Inventory and Land Use Capability

NZ Fundamental Soil Layers

Hybrid between NZLRI and NSD

NZLRI Soil boundaries

Single polygon set – multiple attributes



NZ Fundamental Soil Layers

1st Ed 1999

1:63,360 /1:50,000 scale

100,000 NZLRI polygons

MMU 10ha

Digital

Physiographic units

Single polygon set – multiple attributes

Soil survey & code

Soil series, type, phase

Soil set & genetic group

NZ Soil Classification

Fixed classes
No depth info
Class uncertainty info

pH

Salinity

CEC

Carbon

P retention

Gravel content

Rock & boulders

Depth

Drainage

Available water

Macroporosity

Status of soil information in NZ

Old information inadequate to support
new sustainable management tools

- Old soil data is
  - Patchy
  - Qualitative,
  - Imprecise & Inaccurate

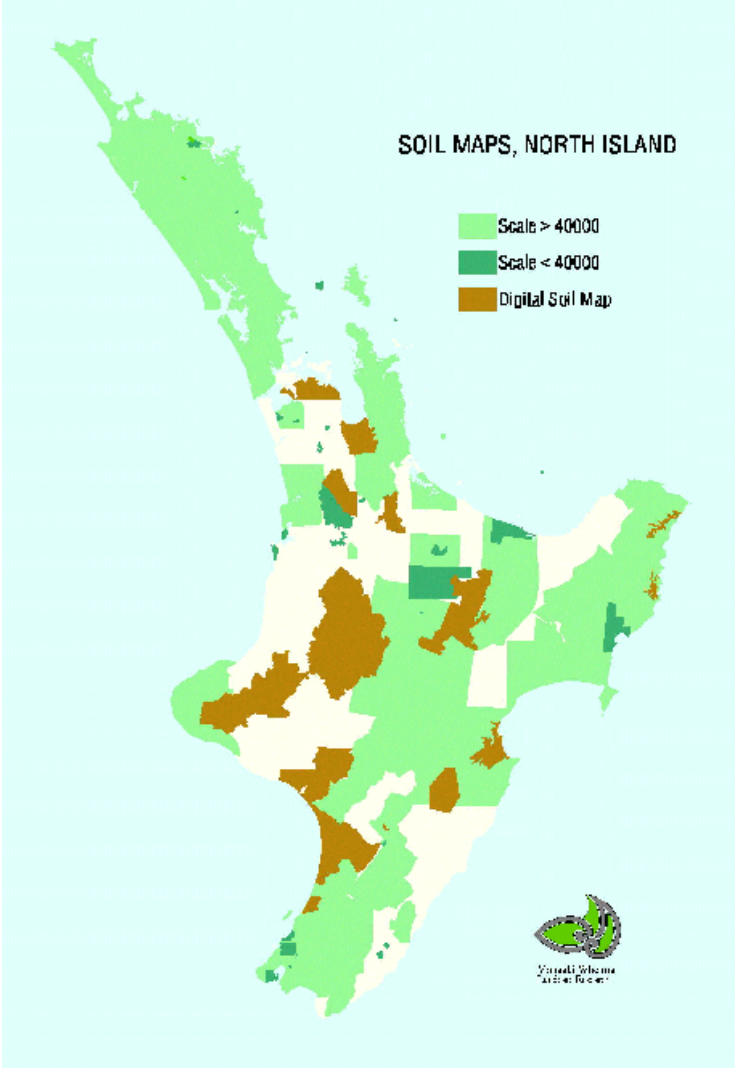
- Reflects needs of the 1950-70s

- Only 700 of our 2000 soils have adequate data

New tools require

quantitative data, better detail

new types of information



S-map

The newest (but incomplete) soil layer

- One soil map for NZ – unified correlation
- Best available data (digital not cartographic)
- Soil only (not climate or topography)
- Combination of soil survey techniques and DSM approaches where appropriate
- Not just data but an inference system
- Many soil and land attributes (whether measured, estimated or derived)
- Explicit uncertainty for all data, and source

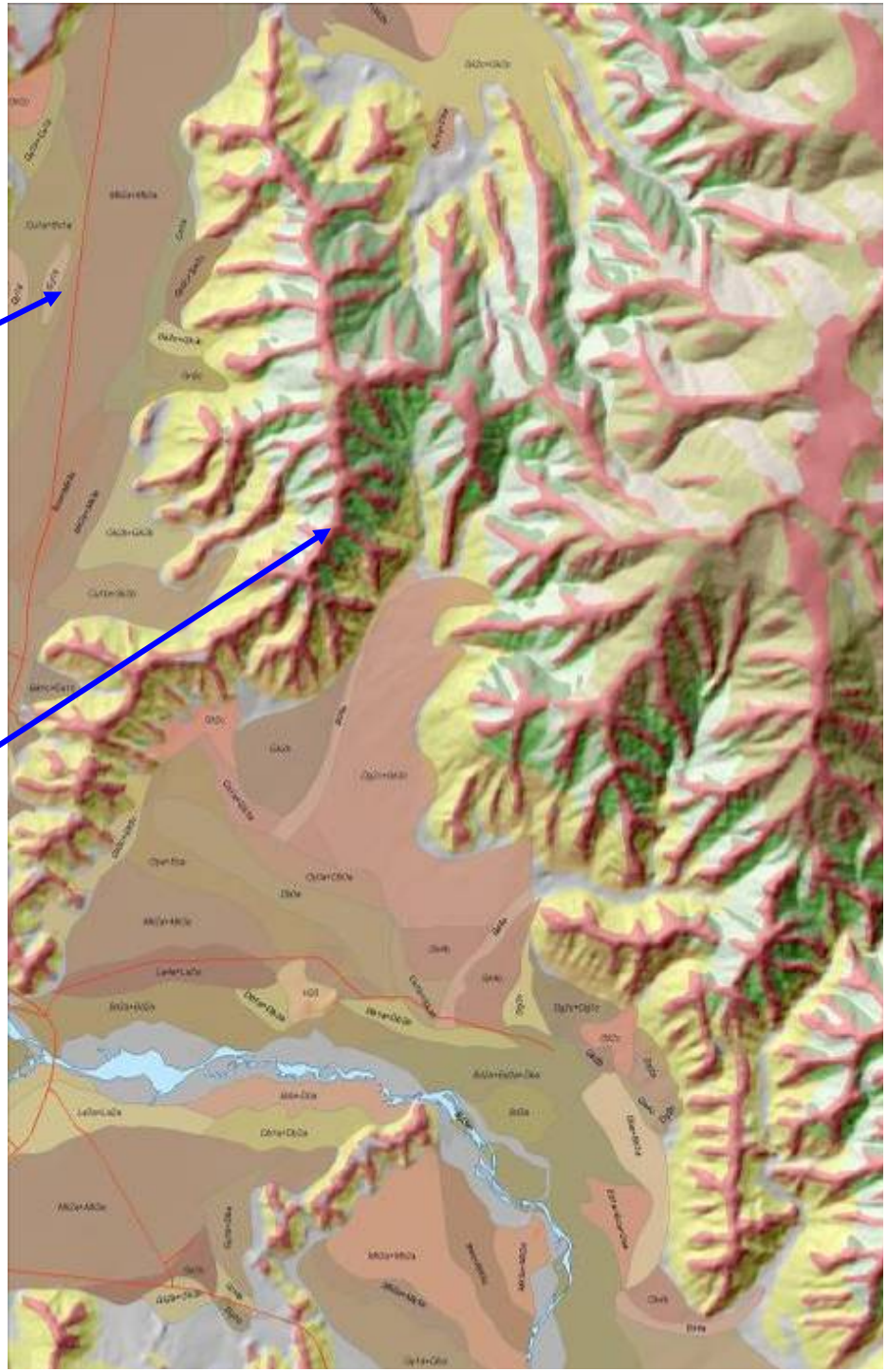
Mapping procedure

- Mixture of conventional soil survey and modelling
  - to new S-map standard
  - Correlating to NZ legend
- New mapping to fill in the gaps
  - Lowlands: conventional soil survey techniques
  - Uplands: model the landscape using a DEM

S-map

Lowlands by conventional survey

Uplands by soil-landscape modelling

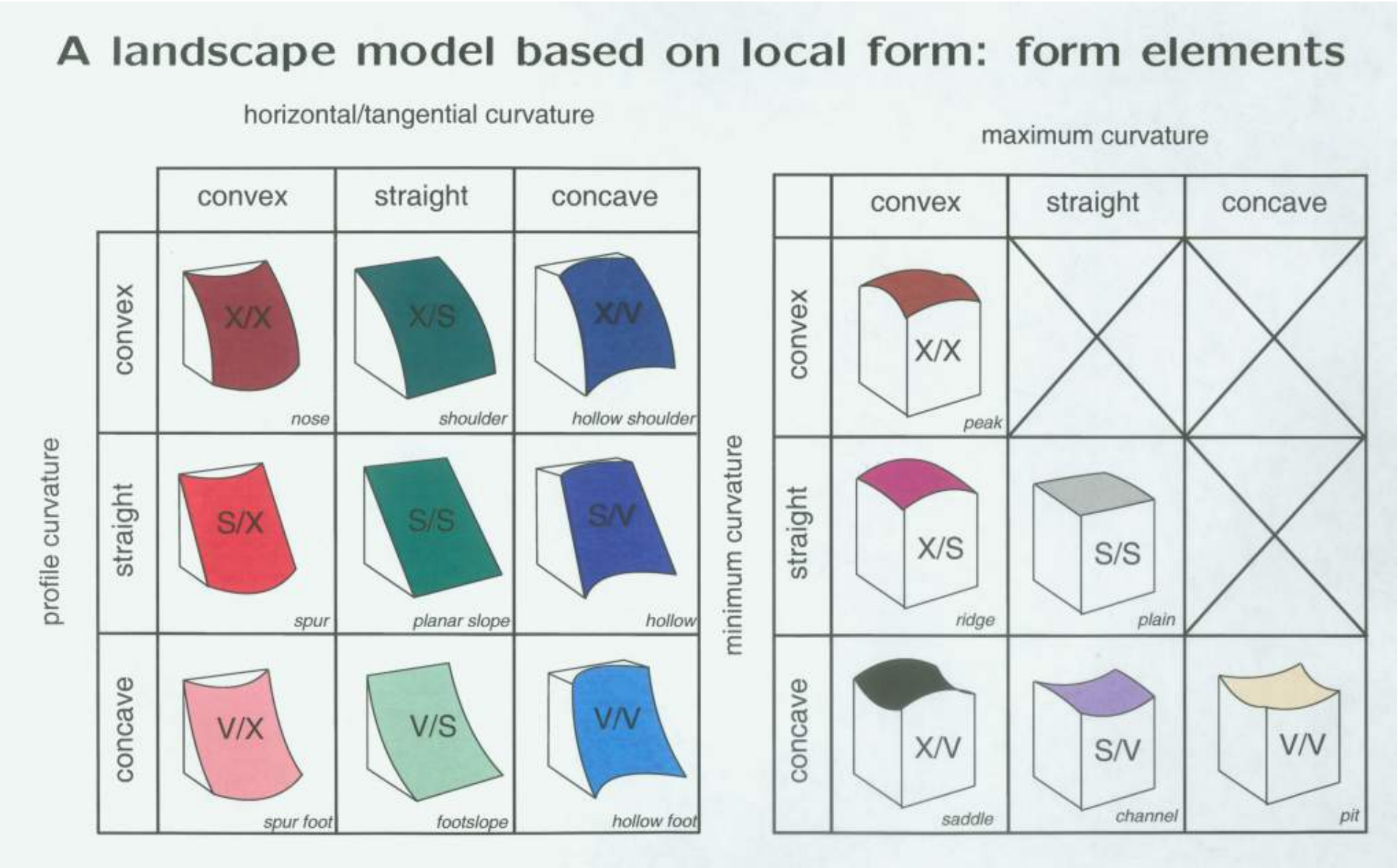


Modelling

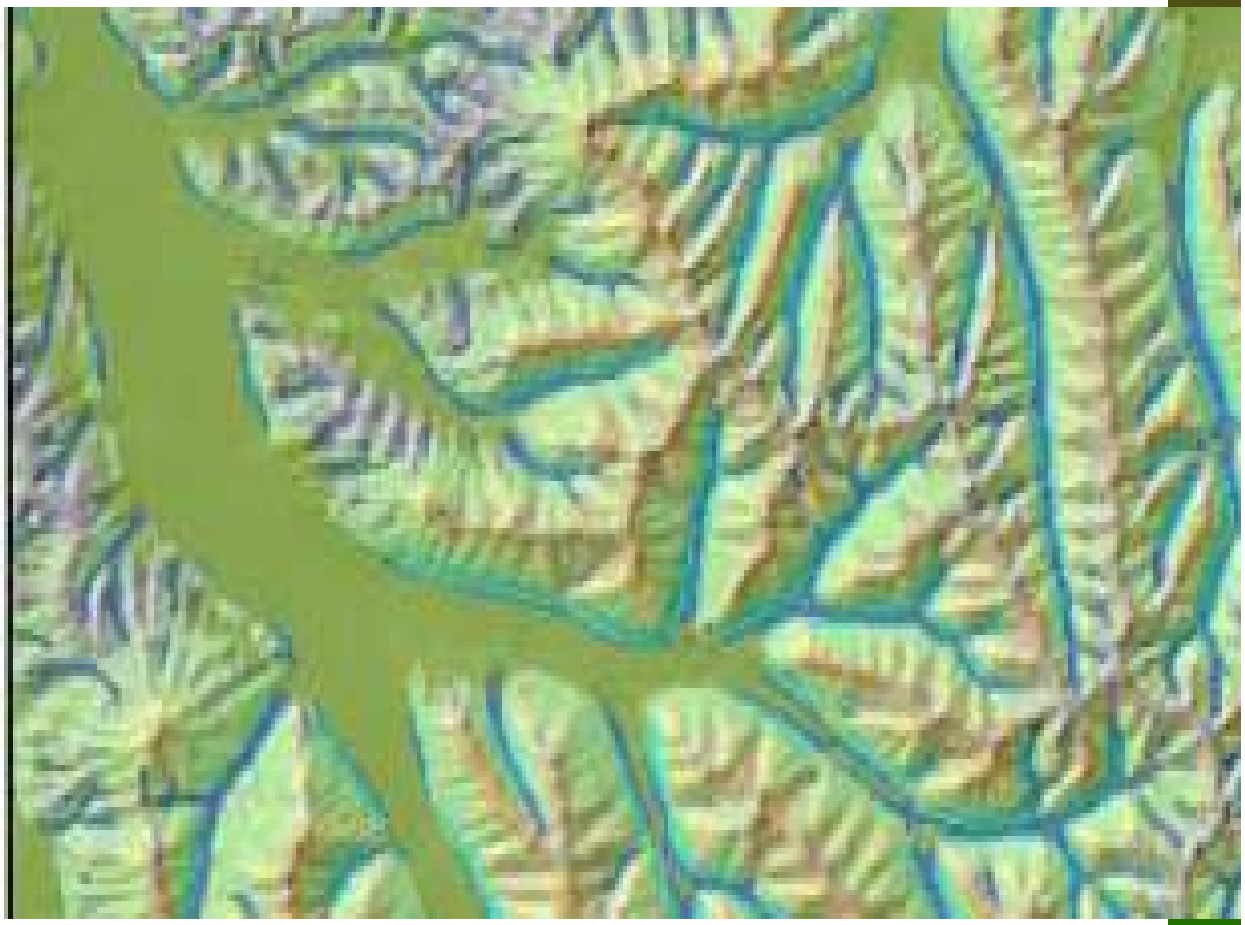
in hilly & mountainous land

- Within land systems - use a DEM to divide a landscape into ‘land elements’
- Use field work and expert knowledge to develop soil-landscape models to predict soils within the land elements
- Models mainly in the form of rules that relate land elements to soil classes and attributes.

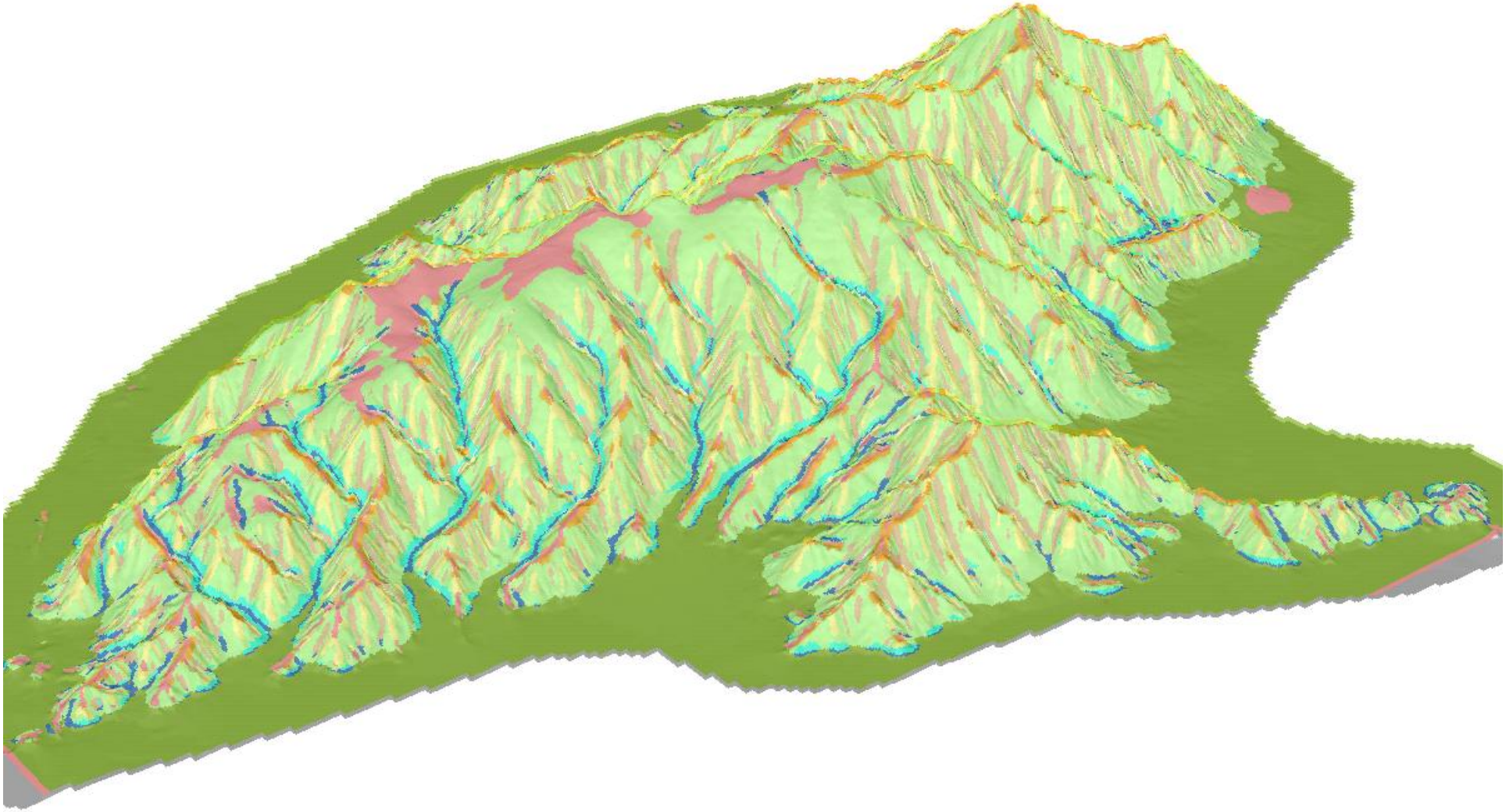
Topographic form elements



Land elements



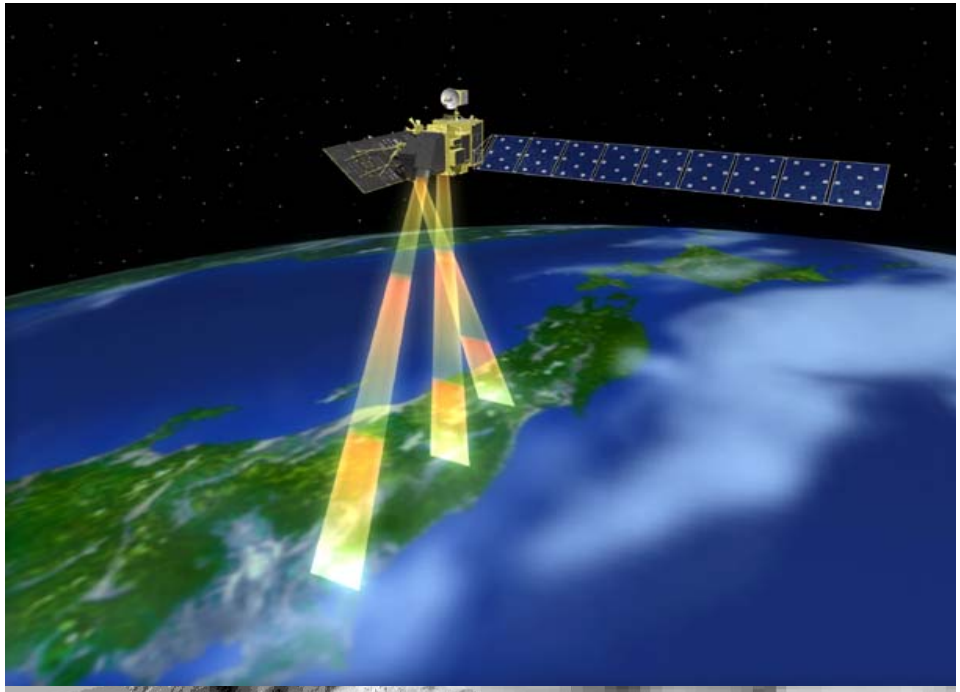
Dry greywacke terrain – Ben More Range
Land Elements



Associating land elements with soils

Landform component	Soil series
ridges	
All elevations and aspects	ORx2z (85%) + TM1z (15%)
Rolling plateau summit	BMa1z (100%)
backslopes	
>1100m	
N aspect	BRa2z (50%) + ORx2z (25%) + BMa1z (25%)
W and E aspects	BMa1z (60%) + BRa2z (25%) + ORx2z (15%)
S aspect	BMa1z (45%) + TM1z (45%) + BRa2z (10%)
>750<1100m	
N aspect	TM1z (70%) + ORx2z (30%)
E aspect	TM1z (60%) + BMa1z (40%)
S aspect	BMa1z (90%) + TM1z (10%)
W aspect	BMa1z (70%) + ORx2z (30%)
<750m	
N, W, and E aspects	ORx2z (65%) + TM1z (35%)
S aspect	TM1z (80%) + ORx2z (20%)

High Resolution DTM



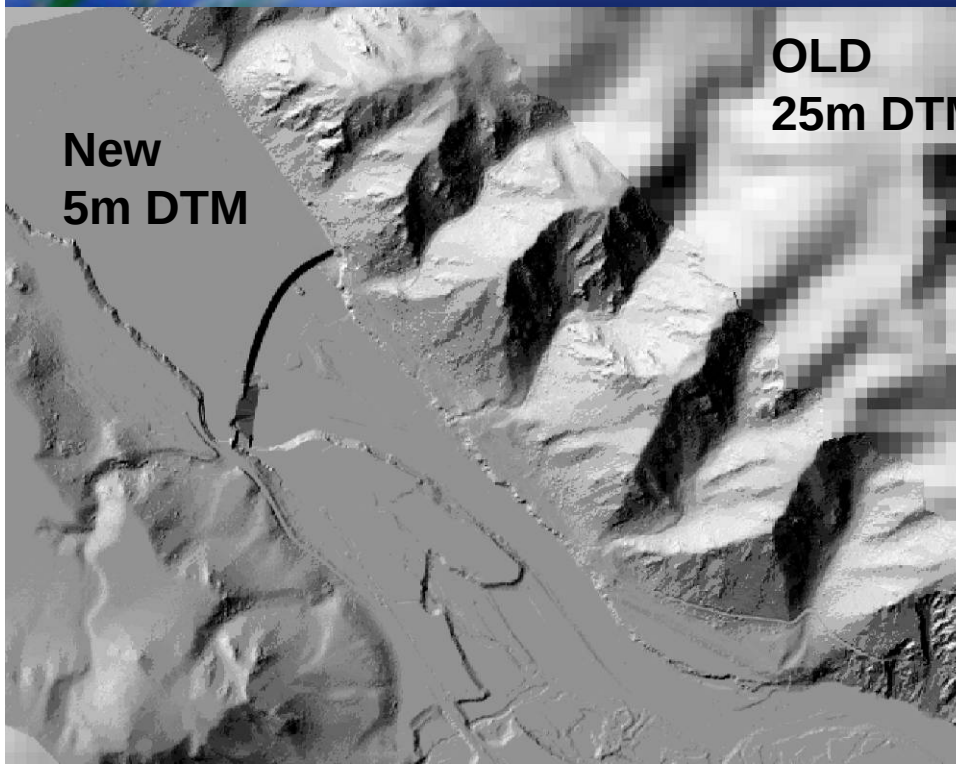
Old 25m DTM
Limited accuracy model soil in detail

Develop high resolution ~ 5m TDM

1st Using ALOS optical imagery
2nd Using Radar imagery

Two trial areas
- **Port Hills**
- **Manawatu soft rock hill country**

Good farm scale analysis possible



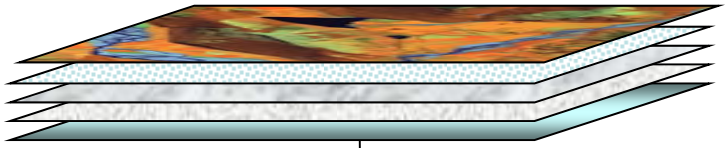
Soil Digital Mapping

Represent soils as rasters rather than polygons

Predicting the most probable soil type & attribute value for every pixel

- **Methods in two trial areas**
  - Port Hills
  - NI soft rock hill country
- NZ Strategy by defining NZ soilscapes
  - to set up spatial predictor data sets
  - To plan a national strategy for matching methods to land type and data resources

Spatial predictors
e.g. climate, landforms, geology



Modelling
e.g. Fuzzy, Bayesian, Regression tree

Predicted soil map

Soil families & siblings

Soil Family

A

Siblings

1 2 3 4 5

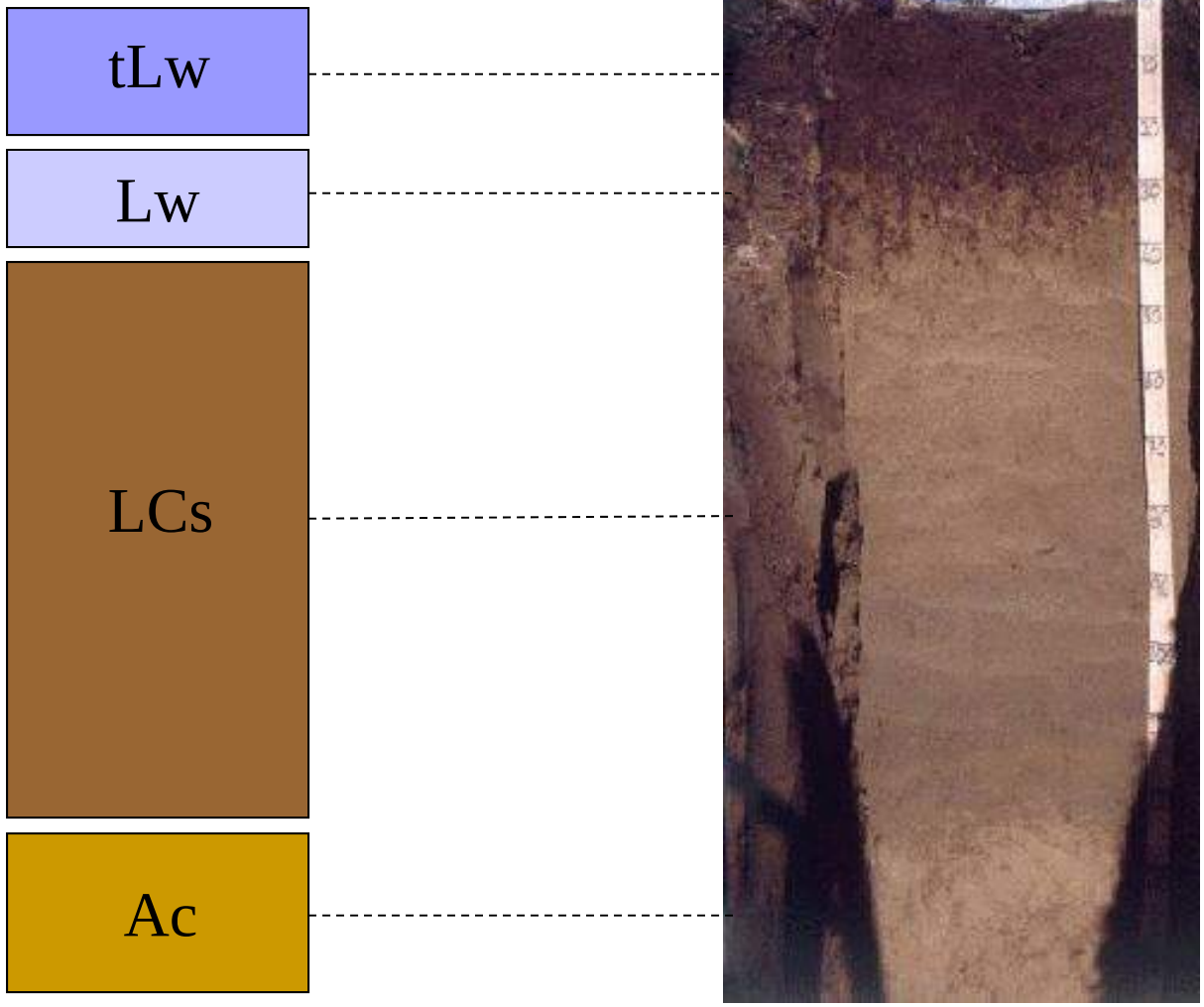
NZSC
Parent Mat.
Rock class
Texture group
Permeability

Depth
Drainage
Texture
Stones
Functional Hor
Misc.

Functional horizons

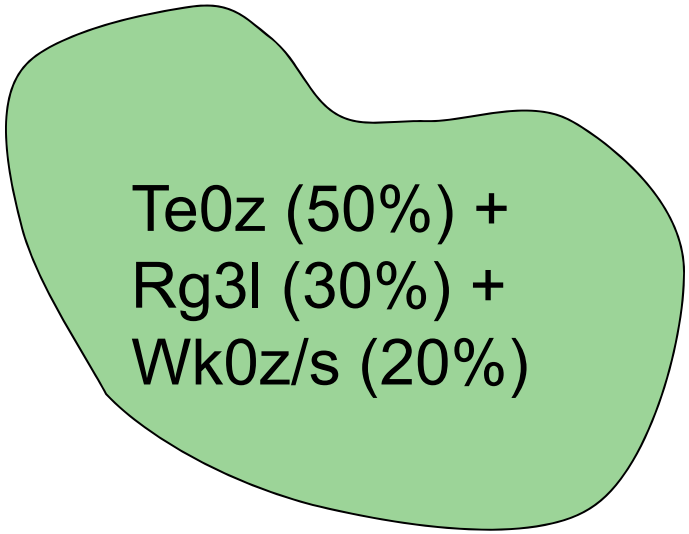
Building blocks for NZ soils

Horizons based on soil physical functions



Soil classes and attributes in the S-map database

Core Dataset (Class data)	**Core Dataset** (as Prob. dist. functions)	**Derived data** (modelled mean and variance)
Soil Order Soil Group Soil Subgroup Soil family Parent material Soil family Parent material Rock Class Texture Group Permeability Depth class Stoniness class Texture Drainage Functional horizons	Depth - Rooting - Diggability - to slow permeable layer Rooting barrier For each Functional horizon: Thickness Stoniness Clay content Sand content	PAW Field capacity Wilting point Aeration Macroporosity Bulk density Total carbon Total nitrogen P (H2SO4) Ca CEC pH P retention



Legend
Te = Templeton*f* family
Rg = Rangitata*f* family
Wk = Wakanui*f* family
0 = deep
3 = shallow
z = silt
l = loam
z/s = silt over sand

Confidence code + qualitative uncertainty code for all classes

Representation of uncertainty (in S-map)

- *Variability described via 5 siblings*
- *Sibling proportion confidence code*

Polygons

Correlation attributes

Models

Base property attributes

- *Confidence code*
- *Alternate codes with probability*

Interpreted and Derived attributes

- *Confidence code (source)*
- *Variability via Pdfs*

- *Propagated error estimates*
- *Model error / goodness of fit*

Code	Description
1	Confident that classification/correlation is correct (based on an acceptable level of auger and pit observations or other data).
2	Reasonably confident that classification/correlation is correct or that it is one of the listed alternatives (based on an acceptable level of auger and pit observations or other data)
3	Classification/correlation is probably correct (based on limited or historical data, or strong inference)
4	Classification/correlation is possibly correct (usually based on reasonable model or poor data)
5	Classification/correlation is unreliable (there is no data or good model, or variability is very high)

Representation of uncertainty (in S-map)

- *Variability described via 5 siblings*
- *Sibling proportion confidence code*

Polygons

Correlation attributes

Models

Base property attributes

- *Confidence code*
- *Alternate codes with probability*

Interpreted and Derived attributes

- *Confidence code (source)*
- *Variability via Pdfs*

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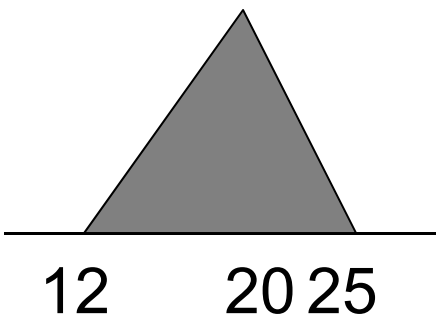
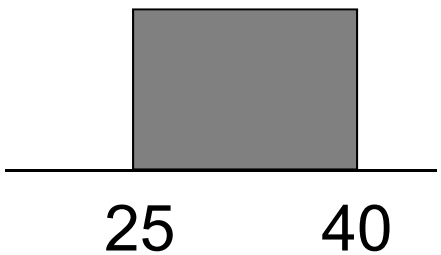
Probability distribution functions

for soil attributes within functional horizons

1st Functional horizon
Thickness (cm)



1st Functional horizon
Stones (%)



Probability distribution functions (pdf)
to express variability and uncertainty

Source of pdf

Code	Observation type	Description
M1	Measured[a]	Unbiased sampling at the individual mapunit level
M2	Measured[a] or Observed	Has at least 15 good quality measurements, widely distributed within the sibling in the survey area, or extrapolated from many highly consistent measurements from a landscape of similar soil material and origin
M3	Observed[b] or measured	Limited sampling, (biased, localised or incomplete)
E	Estimated	Values are estimated by comparison with related soils
G	Unreliable estimate	

All siblings in map unit

Te0z (50%) +
Rg3l (30%) +
Wk0z/s (20%)

Deep (70%) +
Shallow (30%)

by the class proportions

by the weighted average of all the siblings

82 cm

40-100 cm

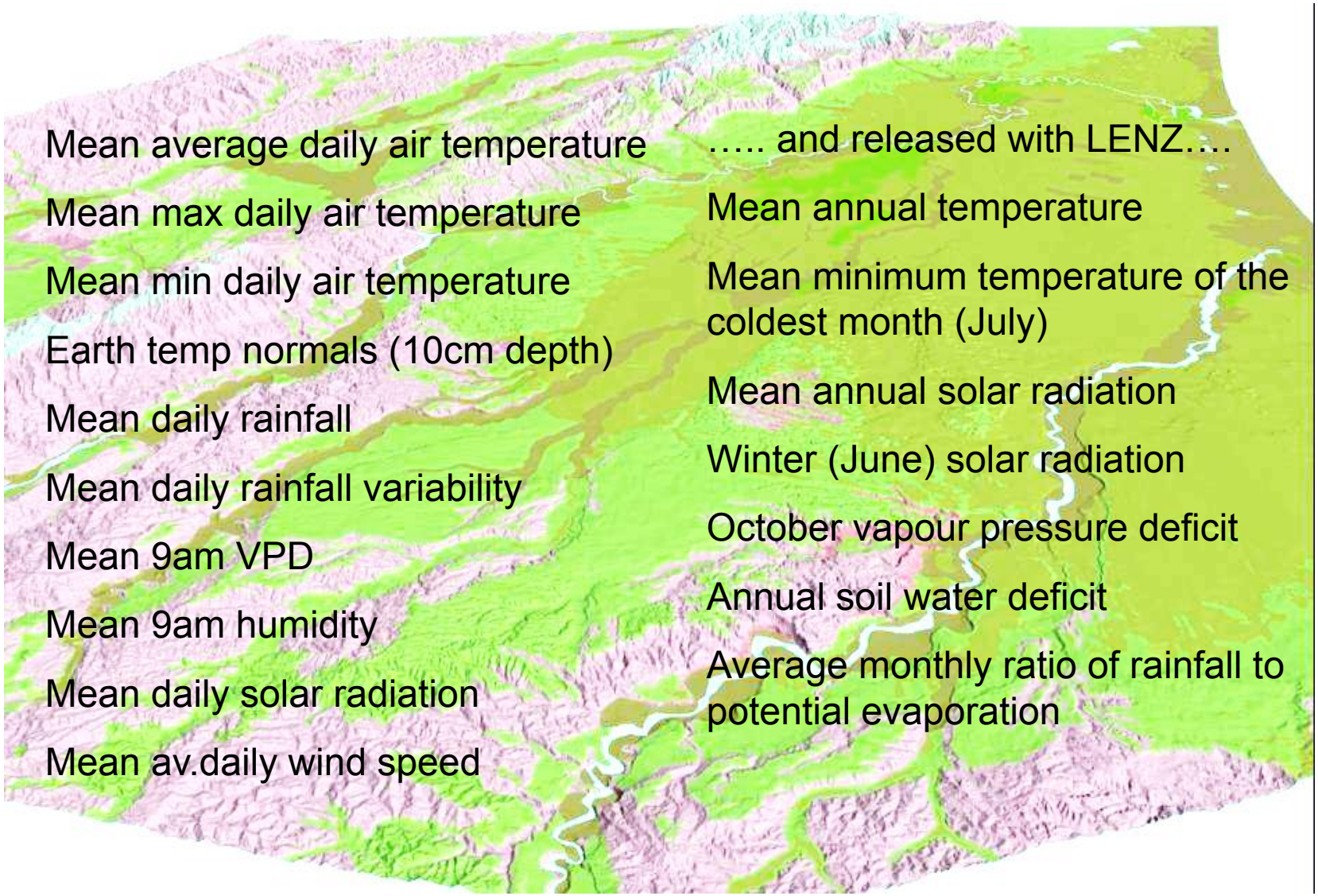
by the range of all the siblings

Primary ancillary layers

- DEM (15m)
- Geology (1:250,000)
- Landcover (25m)
- Landuse (~1:50,000)
- Climate (20 or 25m)

New Zealand Climate Layers

Derived from 100m and 25m DEMs coupled with a thin-plate spline surface fitted to meteorological station data from 1950-1980



Mean average daily air temperature

Mean max daily air temperature

Mean min daily air temperature

Earth temp normals (10cm depth)

Mean daily rainfall

Mean daily rainfall variability

Mean 9am VPD

Mean 9am humidity

Mean daily solar radiation

Mean av.daily wind speed

….. and released with LENZ….

Mean annual temperature

Mean minimum temperature of the coldest month (July)

Mean annual solar radiation

Winter (June) solar radiation

October vapour pressure deficit

Annual soil water deficit

Average monthly ratio of rainfall to potential evaporation

Developing NZ's GSM layers

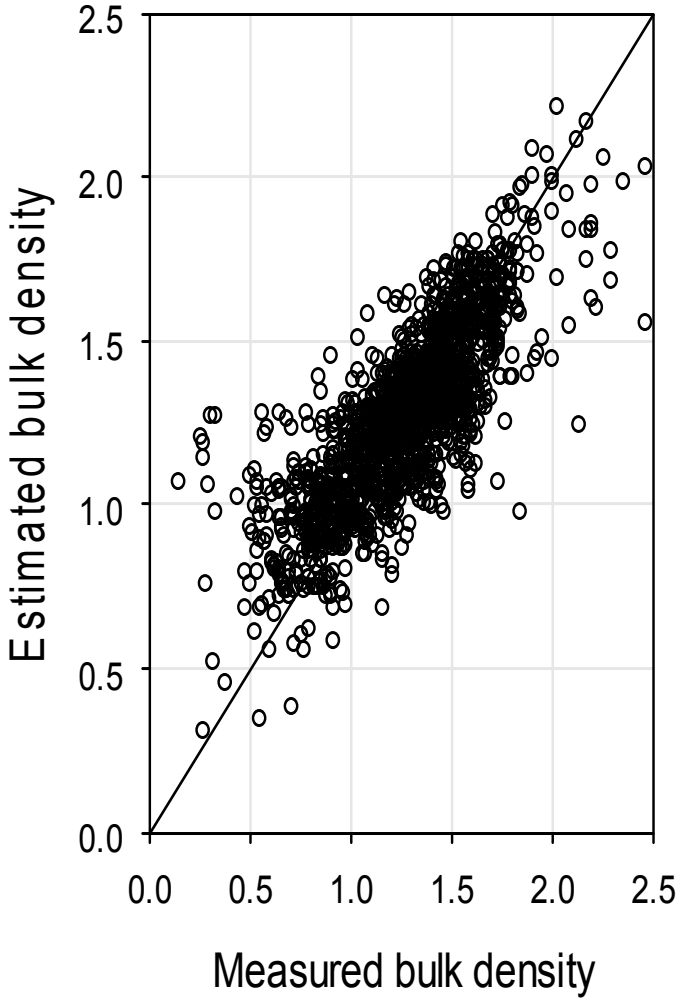
Property	Model
total profile depth (cm),	S-map data + ? Geostats?
Root depth (cm)	S-map pdf data + FSL
Organic Carbon (g/kg)	GLM model
pH	Splines + geostats?
Sand/silt/clay (g/kg)	S-map pdf data + geostats?
Gravel	S-map pdf data + FSL
ECEC ($cmol_c$/kg),	None (FSL for base cations)
Bulk density (fines)	S-map PTF (linear regression model) + ??
Bulk density (whole soil)	
Available water (mm)	S-map PTF (Generalised linear model; Gamma distribution with a log link) + FSL

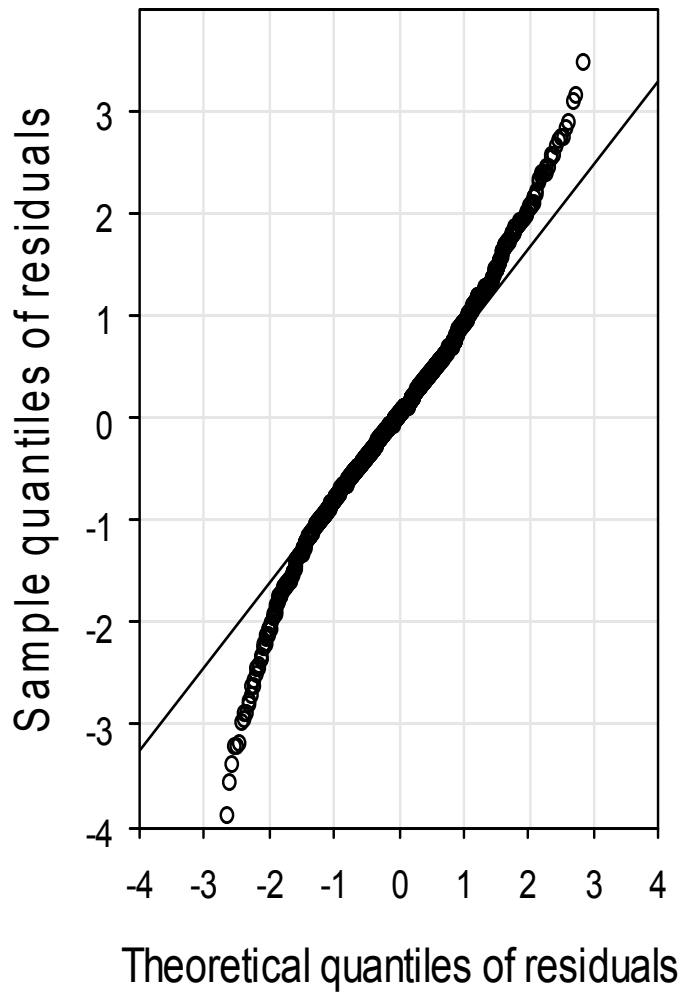
Rooting depth & Gravel

- FSL data is in depth classes – with uncertainty of class

  15-25; 25-45; 45-60; 60-90; 90-120; 120-150 cm
- Gravel is topsoil only
- S-map info is pdfs

Bulk density – S-map PTF





Available water

- GSM PTF (error propagation?)

Or

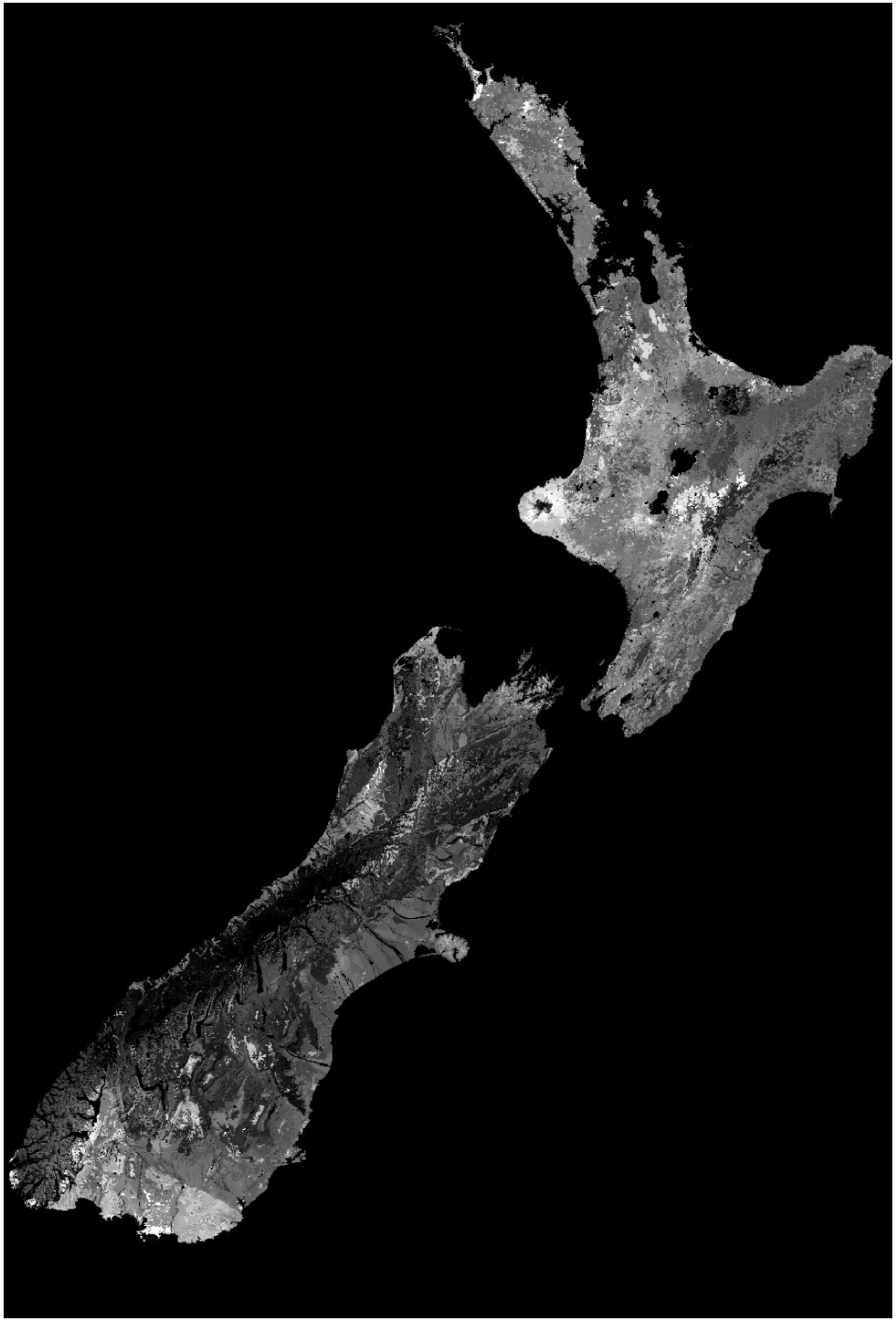
- FSL (classes and whole profile) + S-map PTFs for functional horizons

Clay/silt/sand

- FSL info = silty/sandy/loamy etc (no depth info)
- S-map info is pdfs for functional horizons
- Tried a random forest model for clay at GSM depth intervals using NSD data + 4 covariates

Organic Carbon

- a generalised least squares model predicting log-transformed soil carbon stock (0-30cm)
- ~ a dozen explanatory variables and one interaction, along with a correction for spatial autocorrelation
- 3200+ training samples
- Predicts μ and 95% CI



Some points on uncertainty

- Collecting new statistically sampled evaluation data is not an option
- Which will make uncertainty quantification very difficult
- Will need make use of the splines to match the GSM intervals → uncertainty propagation?
- But we do have some expert knowledge on the reliability of the information
- All our info is only down to 1 m

- S-map supports Monte Carlo approach to providing quantitative estimates of uncertainty **but** …..
- based on expert info