

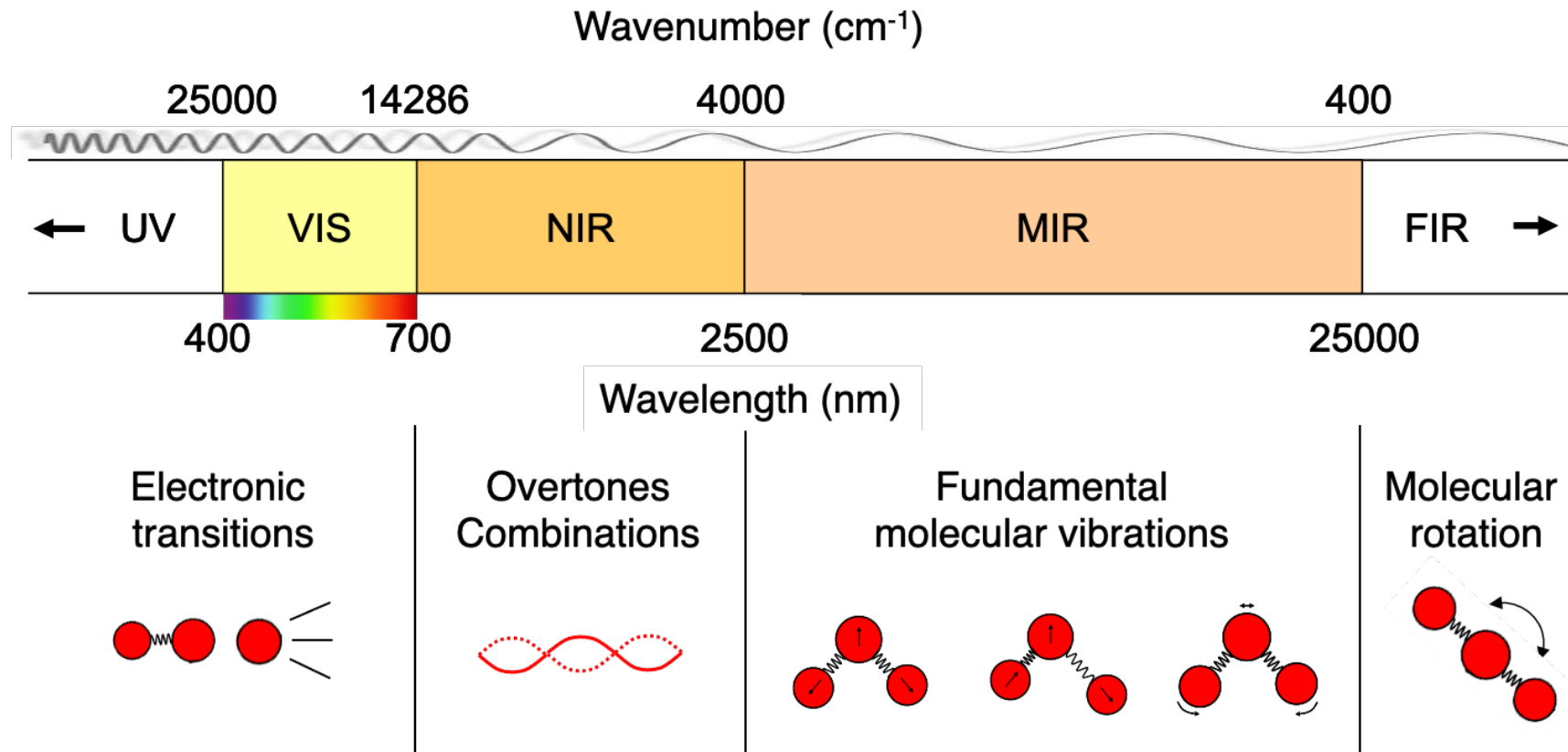


Soil spectroscopy enables digital soil mapping and land resource assessments

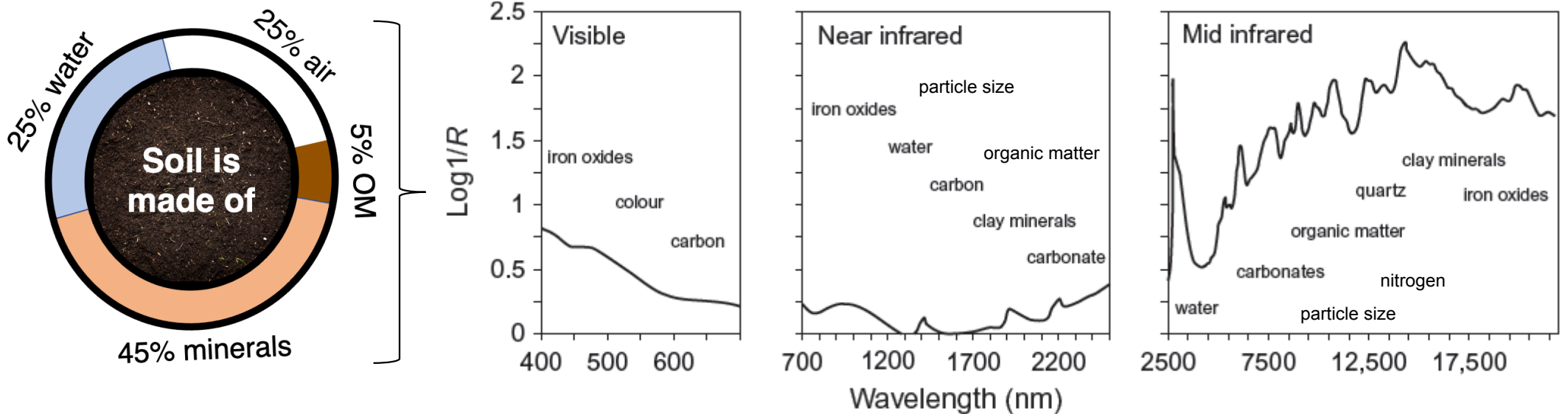
Raphael Viscarra Rossel
Soil & Landscape Science, Curtin University

7th INSII Meeting, 9-10-11 November 2021

Soil spectroscopy



Spectra measure soil composition



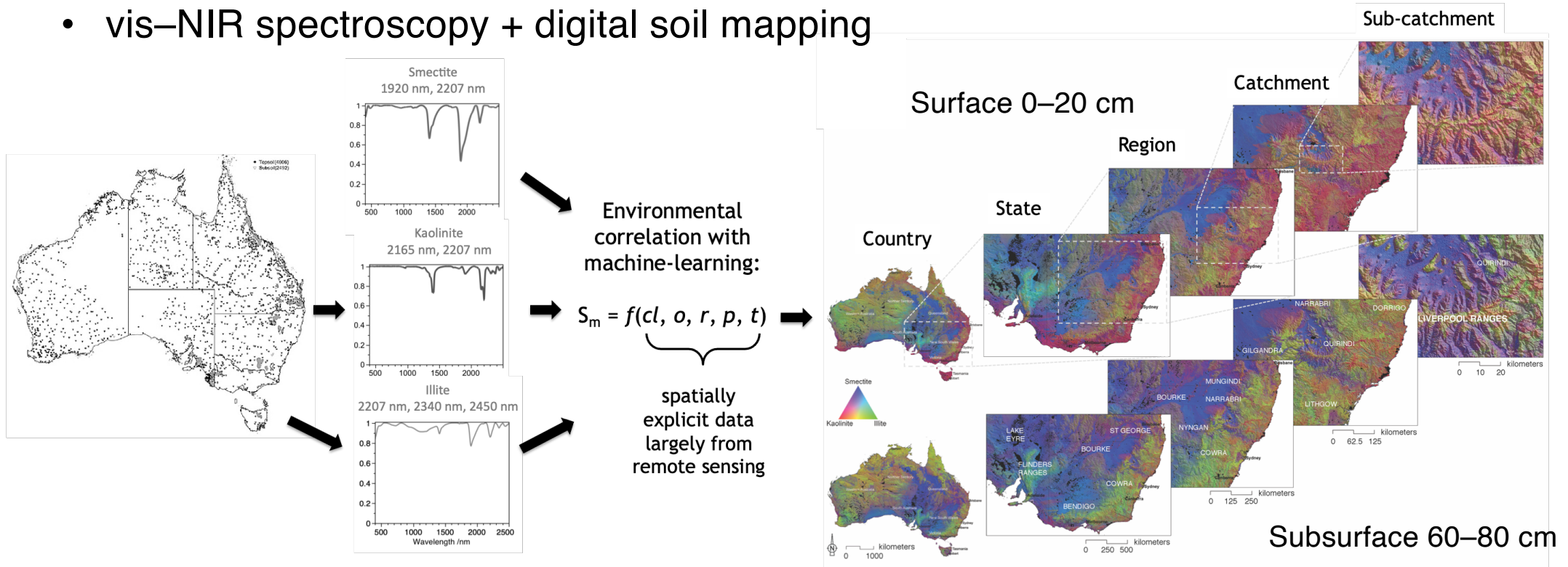
A single spectrum can effectively provide information on the soil and its properties

Digital mapping of the information content of soil spectra



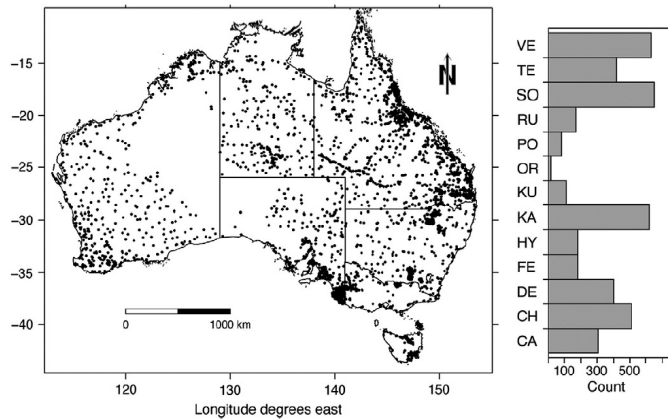
Direct spectral measures of clay mineralogy

- vis–NIR spectroscopy + digital soil mapping



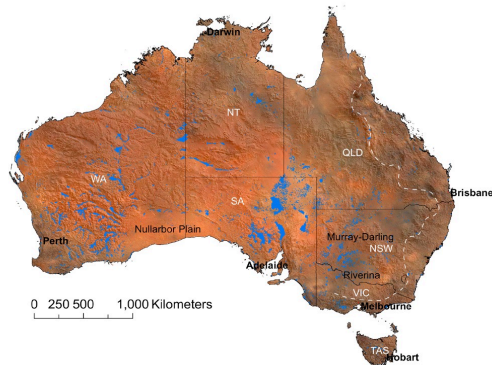
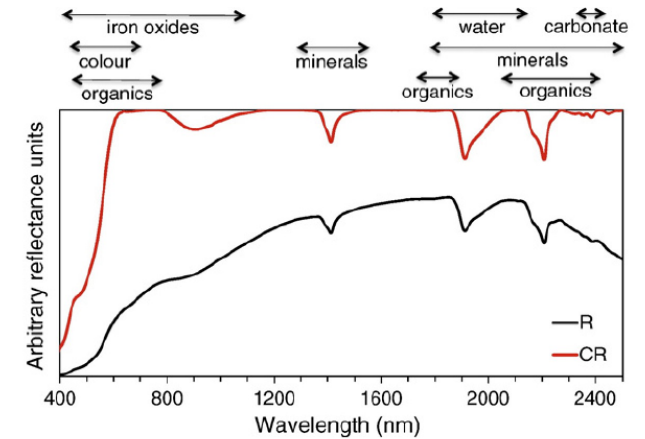
- Filling a gap in soil clay mineral information

Quantifying soil colour, iron oxides, organo-mineral composition

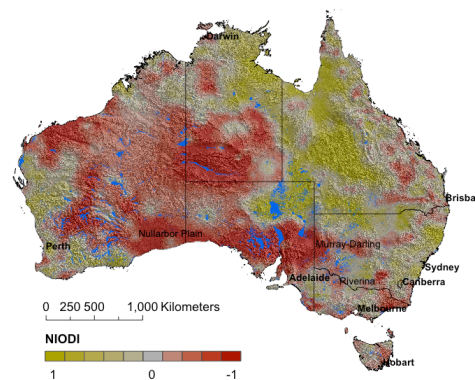


Measured vis–NIR spectra of 5,000+ archived representative soil samples from Australia

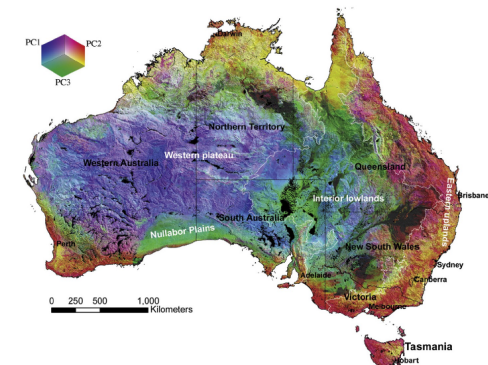
The vis–NIR spectra itself are informative, so digitally mapped their information content



RGB composite but also maps of Munsell HVC



Probability of hematite or goethite



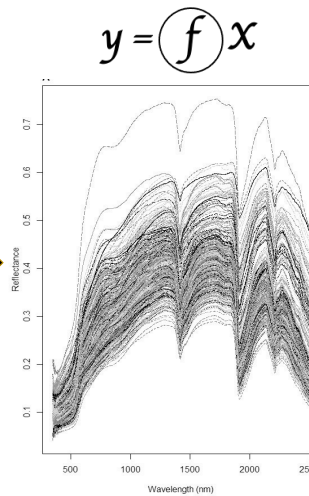
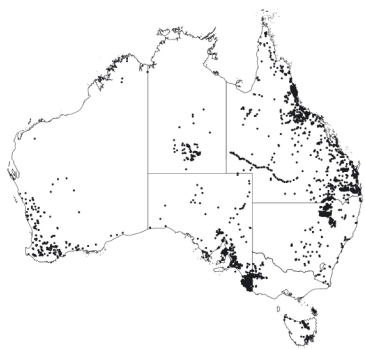
Proxy for soil type 90 x 90 m



Soil spectral libraries and digital soil property mapping

Modelling soil properties requires soil spectral libraries

For example, the Australian spectral library



- CSIRO's soil archive holds 50,000+ soil specimens from with an incomplete set of analytical data
- Measured 20,000+ soils with vis-NIR (& mid-IR)
- Spectroscopic modelling predicted soil attributes

Soil attribute	Mean	RMSE	SDE	ME	RPD
$\theta_{FC} / m^3 m^{-3}$	0.32	0.06	0.06	-0.004	1.68
$\theta_{PWP} / m^3 m^{-3}$	0.16	0.04	0.04	-0.001	1.95
$\text{Log}_{10}(W)$	0.56	0.21	0.21	0.005	1.54
Bulk density / $g\ cm^{-3}$	1.32	0.15	0.15	-0.003	1.87
Clay / %	32.0	8.49	8.48	0.51	2.35
Silt / %	12.5	5.50	5.47	0.58	1.63
Coarse sand / %	30.4	13.56	13.50	1.29	1.61
Fine sand / %	26.1	9.77	9.74	0.74	1.60
Total sand / %	55.1	12.00	12.00	-0.13	2.06
$\text{Log}_{10}(\text{Organic C})$	-0.26	0.25	0.25	-0.01	2.17
$\text{Log}_{10}(\text{Total K})$	-0.50	0.33	0.33	-0.04	1.87
$\text{Log}_{10}(\text{Total N})$	-1.30	0.25	0.25	0.001	2.11
$\text{Log}_{10}(C:N)$	1.18	0.19	0.19	-0.001	1.40
$\text{Log}_{10}(\text{Total P})$	-1.66	0.27	0.27	0.00	1.75
$\text{Log}_{10}(\text{Available P})$	0.91	0.42	0.42	0.007	1.39
pH_{Ca}	5.31	0.57	0.57	0.05	2.16
pH_{Water}	6.95	0.63	0.63	0.002	2.28
$\text{CEC} / \text{cmol}(+) \text{kg}^{-1}$	15.6	7.08	7.06	0.51	2.13
$\text{Log}_{10}(\text{Exch. acidity})$	0.42	0.28	0.28	0.009	1.49
$\text{Exch. Ca}^{2+} / \text{cmol}(+) \text{kg}^{-1}$	7.91	3.77	3.77	0.17	2.34
$\text{Log}_{10}(\text{Exch. K}^+)$	-0.49	0.34	0.34	-0.02	1.65
$\text{Exch. Mg}^{2+} / \text{cmol}(+) \text{kg}^{-1}$	5.49	2.58	2.58	0.16	2.30
$\text{Log}_{10}(\text{Exch. Na}^+)$	-0.41	0.37	0.37	0.0005	2.10
Extractable Fe / %	4.65	2.61	2.61	0.05	1.81

The Australian soil organic C baseline – facilitated by spectroscopy

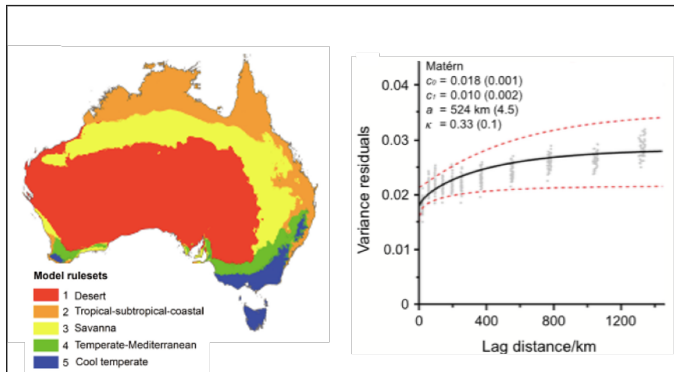
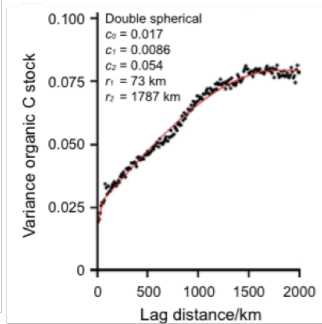
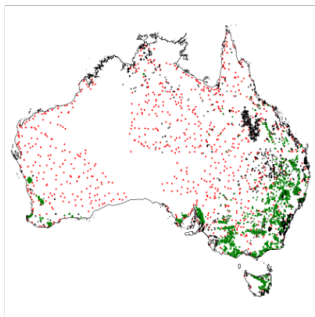
Years 2000 to 2013 only

SCaRP data vis-NIR estimates Legacy data

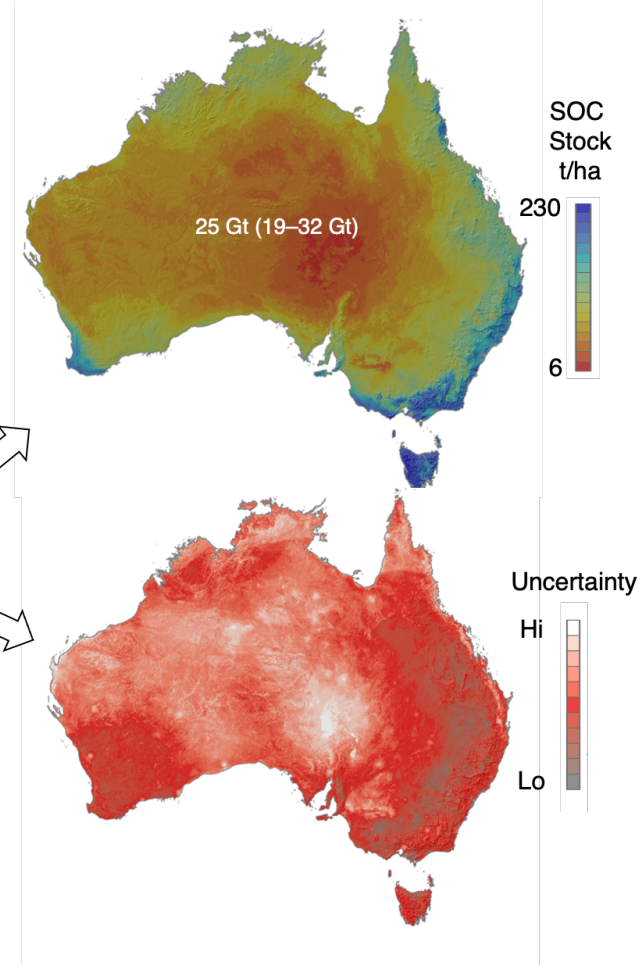
Harmonised to 0–30 cm

$$C_S = (C \times \rho) \times (1-g)$$

$$\hat{C}_S^b(\mathbf{u}_0) = \hat{\mu}_S^b(\mathbf{u}_0) + \hat{\varepsilon}_S^b(\mathbf{u}_0)$$

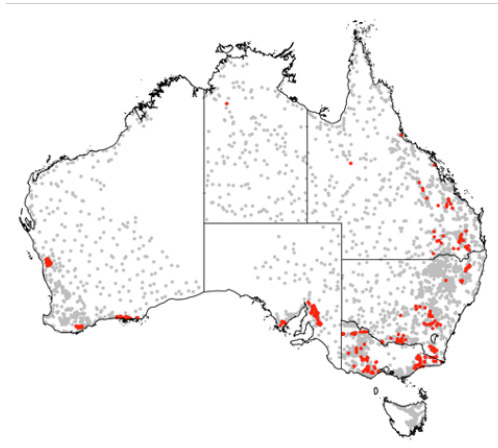


Continently, climate is the biggest driver in the modelling. Regionally, soil, mineralogy, terrain and vegetation are important.



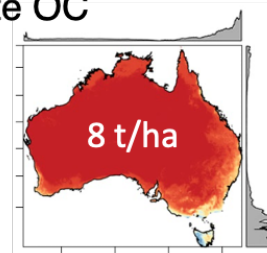
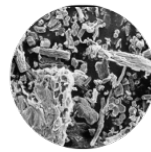
Spatial modelling of soil C composition – facilitated by spectroscopy

- **Physical fractionation & NMR**
- Spectral estimates of the POC, MAOC, PyC

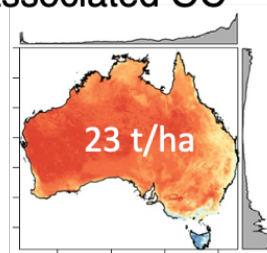
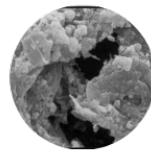


- Digital soil mapping of the C fractions using environmental correlation with machine learning

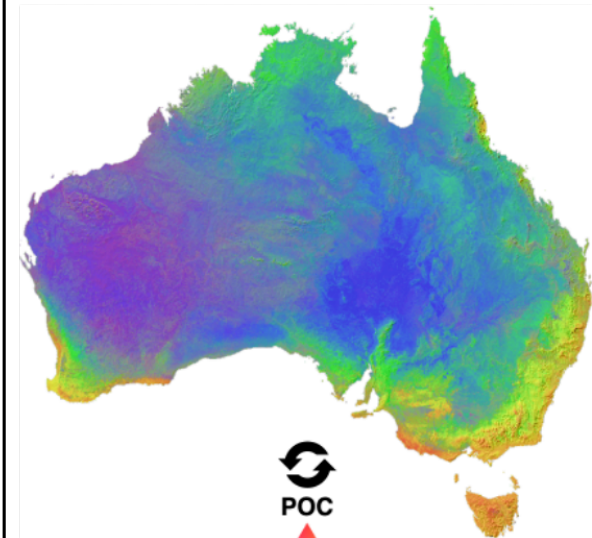
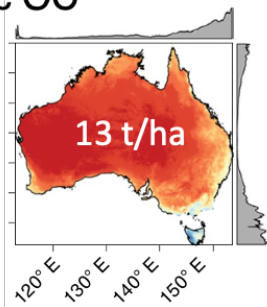
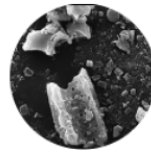
Particulate OC



Mineral-associated OC

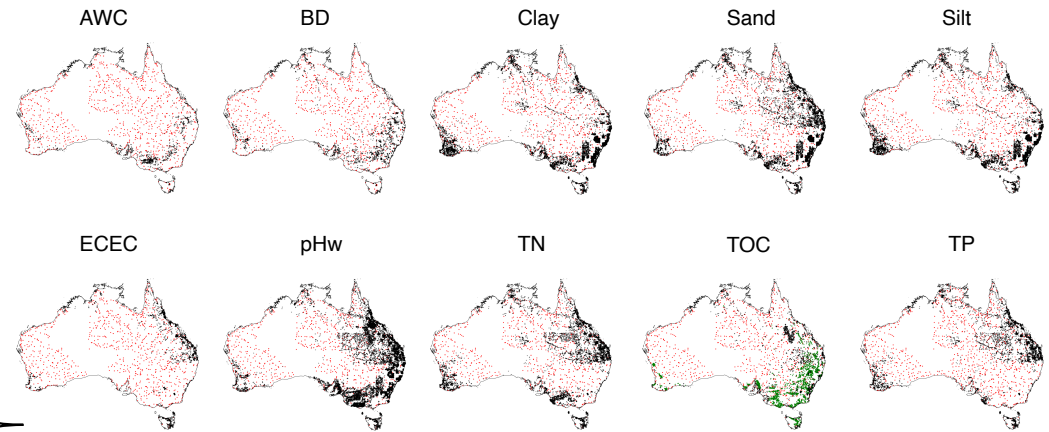
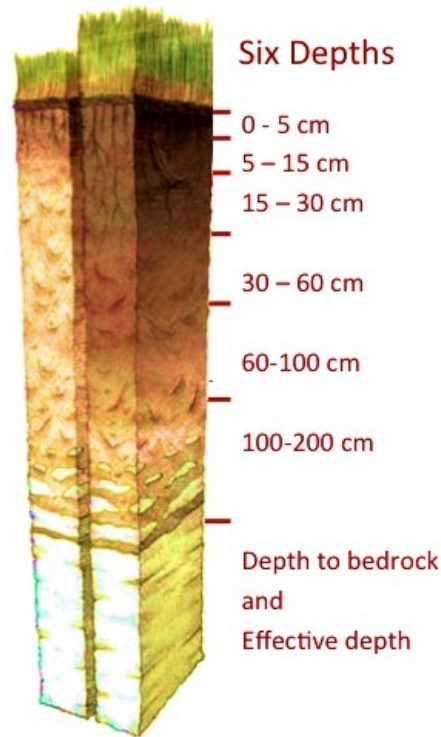


Pyrogenic OC



Australian digital soil property mapping enabled by spectroscopy

SLGA project to derive spatially explicit soil information to better understand interactions with other ecosystem components.

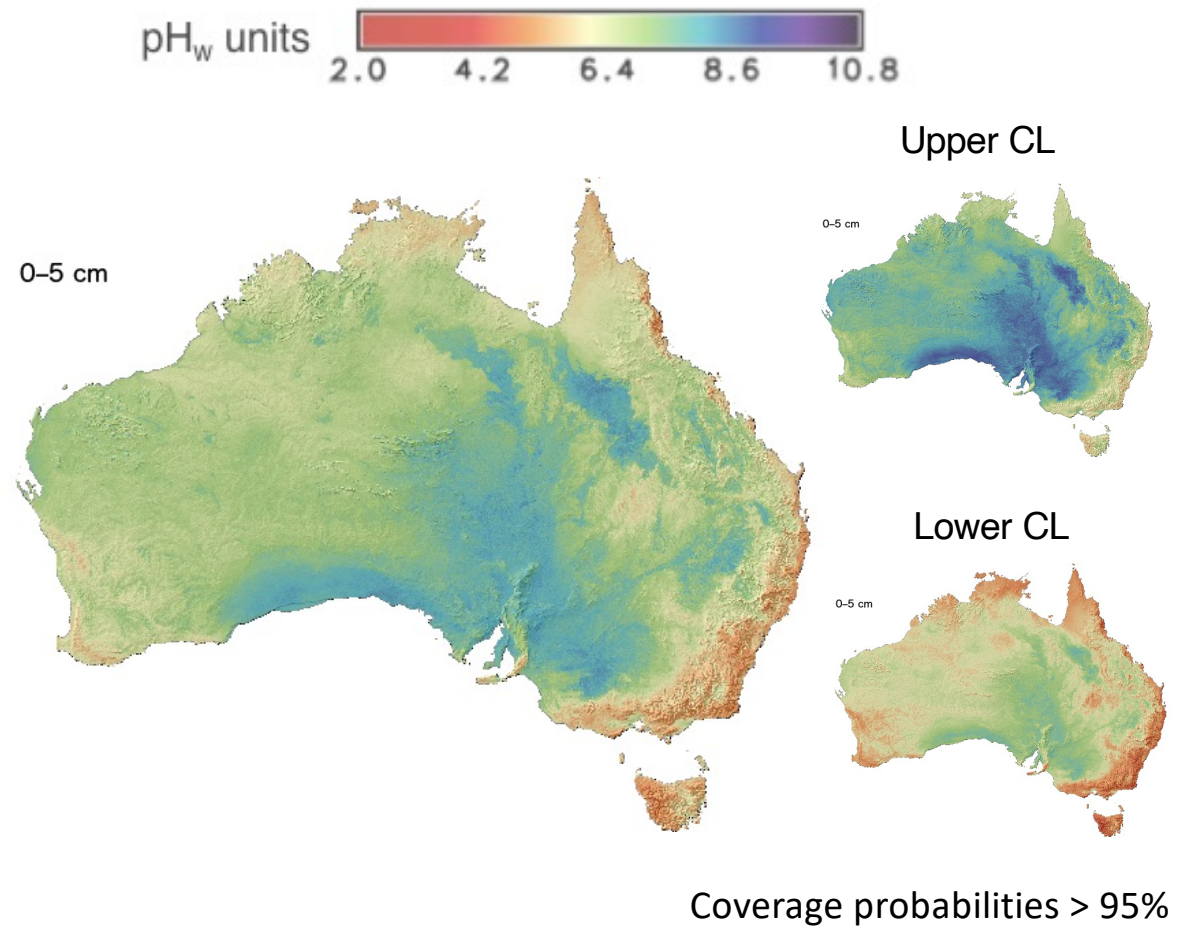
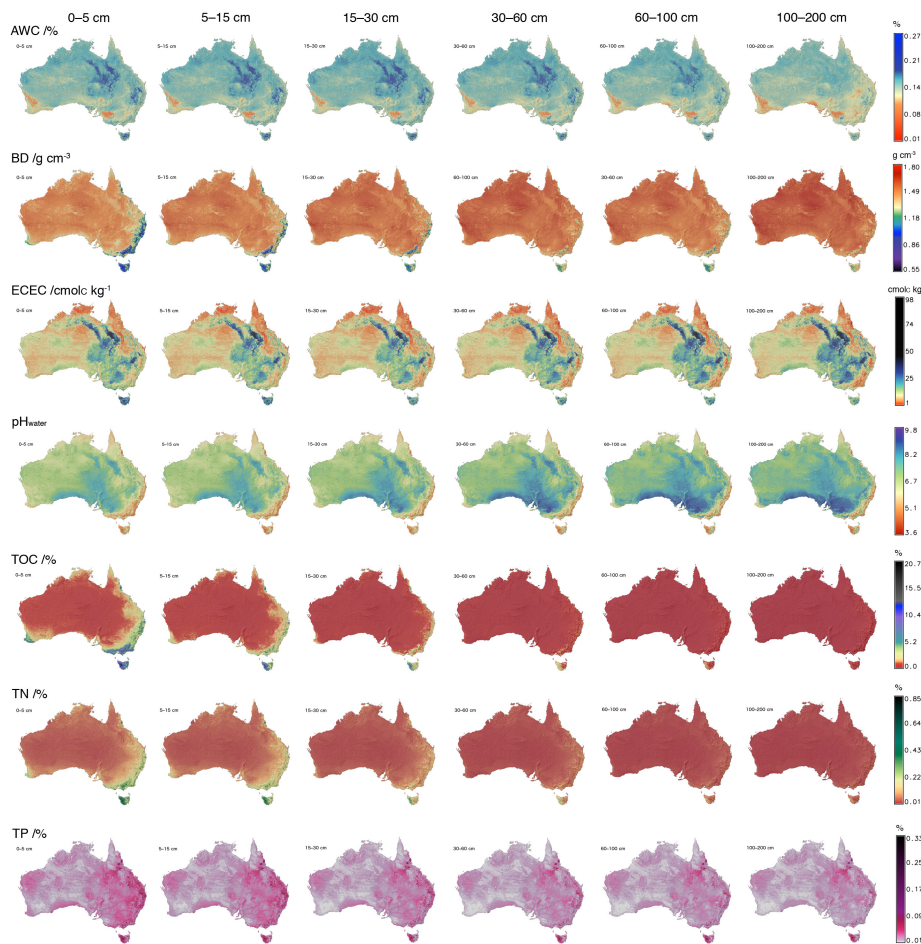


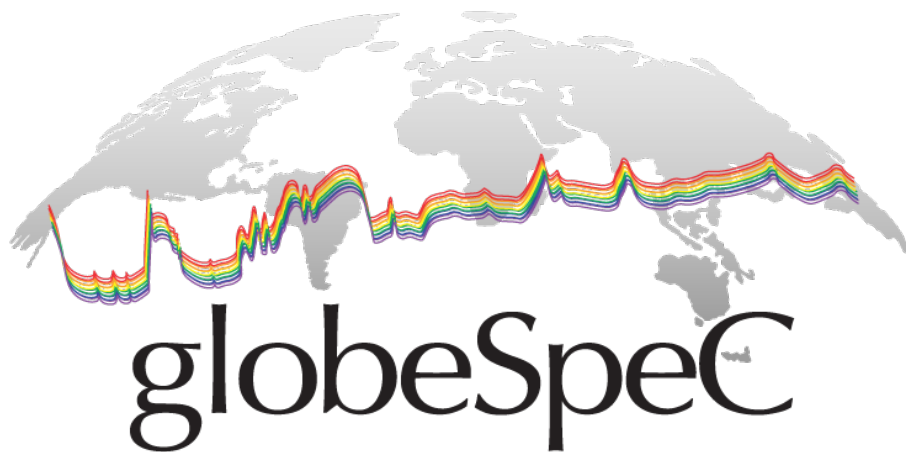
Combined soil property data + **spectroscopic predictions** of soil attributes enabled **continental scale digital soil mapping**: $S_a = f(cl, o, r, p, t)$

$$\widehat{S}_A^b(\mathbf{u}_0, d) = \widehat{\mu}_A^b(\mathbf{u}_0, d) + \widehat{\varepsilon}^b(\mathbf{u}_0, d)$$



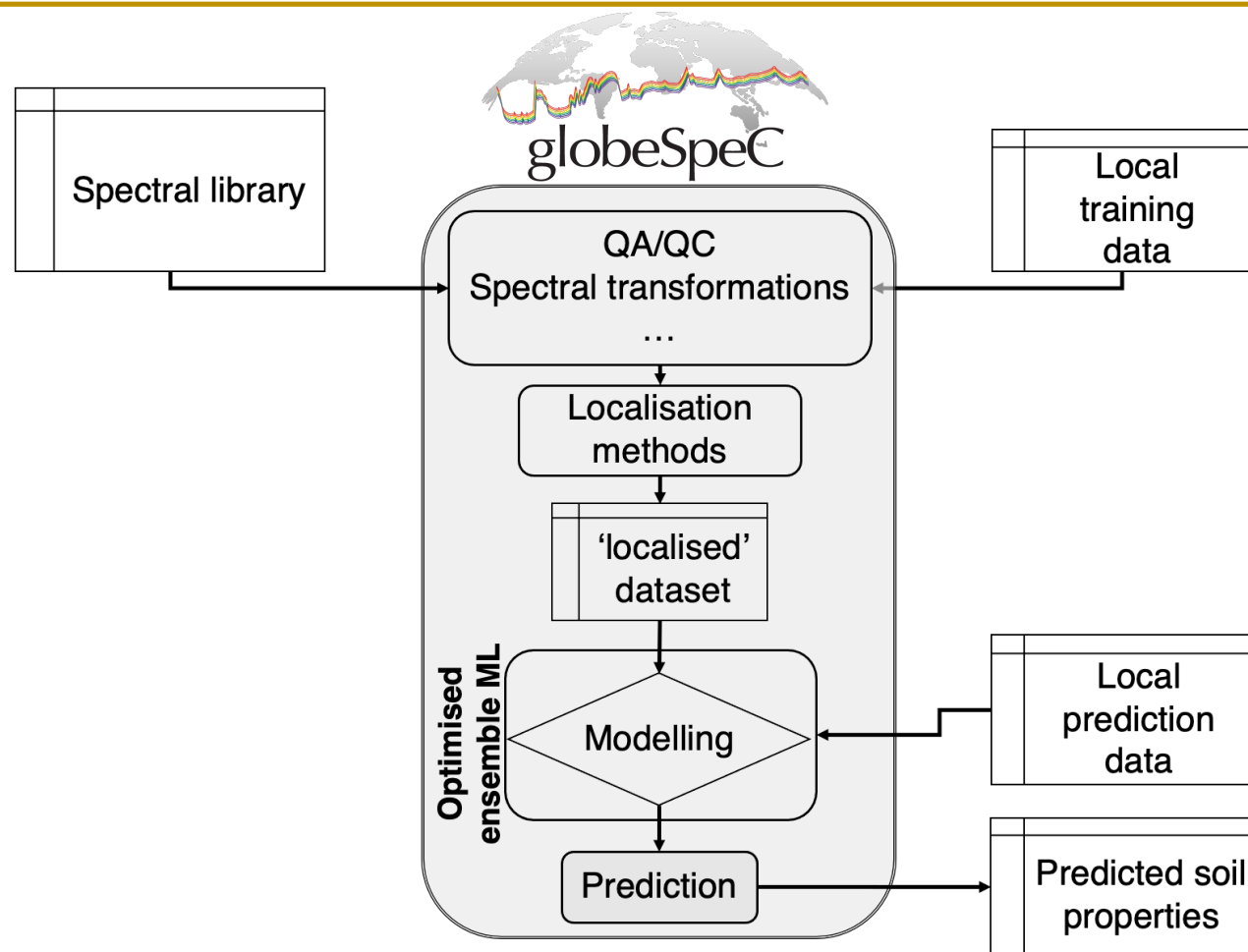
3D maps of soil properties





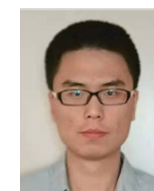
- An online software platform to enables development and use of large (country, global) spectral libraries and localized spectral predictions
- Developed to be
 - versatile,
 - minimise complexity,
 - dynamic and
 - enable continual growth of library
- Accessible by land managers, farmers, researchers ...anywhere in the world and for the common good

Development



R.A. Viscarra Rossel

- concept
- algorithms
- design
- testing



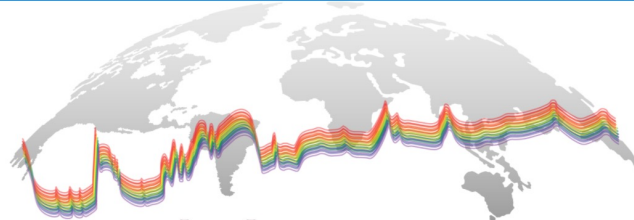
Z. Shen

- development
- algorithms
- testing



L. Ramirez-Lopez

- algorithms
- testing



globeSpeC

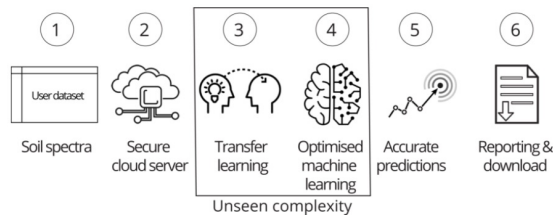
A global platform for local soil spectral predictions

Our aims

Fair and rapid access to local estimates of soil properties using spectroscopy. Less complex, more accurate spectroscopic modelling. For farmers, land managers and researchers around the world.

The platform

A platform for local spectroscopic modelling and the prediction of soil properties anywhere. Using the latest modelling and machine learning to accurately predict important soil properties like total organic carbon (TOC).



globeSpeC v0.1

- improvements to functionality
- broader testing
- proposed hosting at FAO under the GLOSOLAN-spec initiative

(spectroscopy can make more of a difference in less wealthy countries where the cost of soil information might be limiting)

New project

Title	Status	Actions
dataset1_CN	predicted	Download Delete
dataset2_IL	predicted	Download Delete
dataset3_SW	predicted	Download Delete
dataset4_US	predicted	
dataset5_WA	predicted	
dataset7_WA	predicted	
glosolan test 3	predicted	

Previous

New project


Upload data
for training
and prediction

Project page

List of projects

Download report and predictions

Delete projects

globeSpeC [About](#) [Contact us](#) 

[Projects](#) ▸ [Upload](#) ▸ [Check](#) ▸ [Predict](#) Project title: glosolan test 3

How to create a new project:

- Add a descriptive project title (up to 20 characters).
- Add a brief description of the project (100 characters).
- Upload your 'training' data file, prepared as follows:
 - First row (header) contains variable names
 - First column contains sample identification values
 - Second and third columns contains coordinates (Longitude and Latitude) of the samples.
 - Forth column contains the response variable (e.g. total soil organic carbon content values).
 - Remaining columns contain the independent variable (that is, the spectral values for wavelengths in the range between 400 nm and 2500 nm)
 - Save as a comma-separated values (CSV) file.
- Upload your 'prediction' data file, prepared as follows:
 - First row (header) contains variable names
 - First column contains sample identification values
 - Second and third columns contains coordinates (Longitude and Latitude) of the samples.
 - Remaining columns contain the independent variable (that is, the spectral values for wavelengths in the range between 400 nm and 2500 nm)
 - Save as a comma-separated values (CSV) file.

Project details and file upload

Project title:

Description:

demo

Training data: No file chosen

Prediction data: No file chosen

globeSpeC About Contact us

Projects > Upload > Check > Predict Project title: glosolan test 3

User data: assign column names

Training data

ID	Longitude	Latitude	TOC				
ID	Lon	Lat	SOC_perc	400	410	...	2490 2500
1T-1	-92.1217	39.2275	1.9388	0.1256	0.128	...	0.1321 0.3699
3T-2	-92.1217	39.2278	1.086	0.1411	0.1408	...	0.1443 0.3597
8T-1	-92.1217	39.2287	2.5208	0.1068	0.1113	...	0.1166 0.3665
9T-1	-92.1217	39.2289	1.5071	0.148	0.149	...	0.1532 0.2957
22T-2	-92.1216	39.2313	1.0946	0.1156	0.1202	...	0.1248 0.4207

Prediction data

ID	Longitude	Latitude					
ID	Lon	Lat	400	410	...	2490 2500	
1T-2	-92.1217	39.2275	0.1217	0.1231	...	0.1253 0.3299	
2T-1	-92.1217	39.2277	0.1158	0.1207	...	0.1242 0.3246	
2T-2	-92.1217	39.2277	0.1232	0.13	...	0.1351 0.3333	
3T-1	-92.1217	39.2278	0.1166	0.1257	...	0.126 0.3365	
4T-1	-92.1217	39.228	0.1456	0.1486	...	0.152 0.4179	

TOC content unit:

Type of spectra:

First wavelength: nm

Last wavelength: nm

Wavelength interval: nm

Local TOC distribution

Local spectra

Assign data and upload

Localisation and optimized modelling in near real-time: between 2–6 minutes depending on dataset

Run globeSpeC

Results displayed on a single page

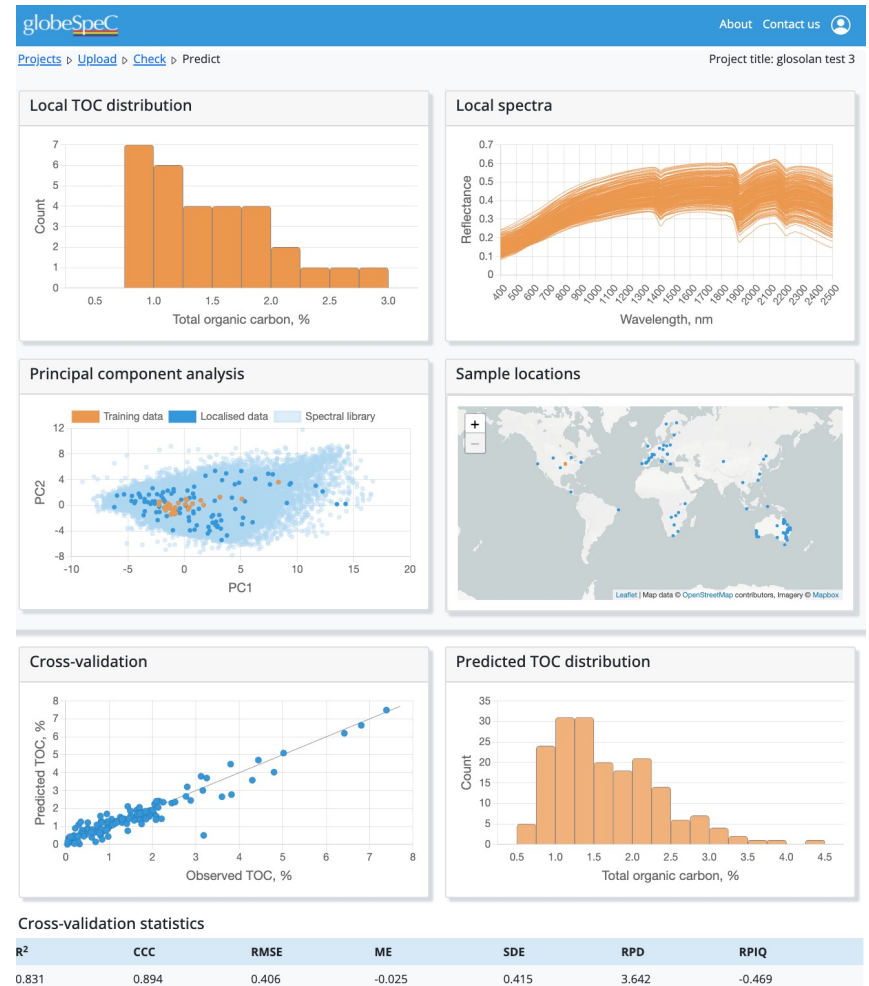
Local data: soil property and spectra

Localised data selection and geolocation

Validations and predictions

Evaluation statistics

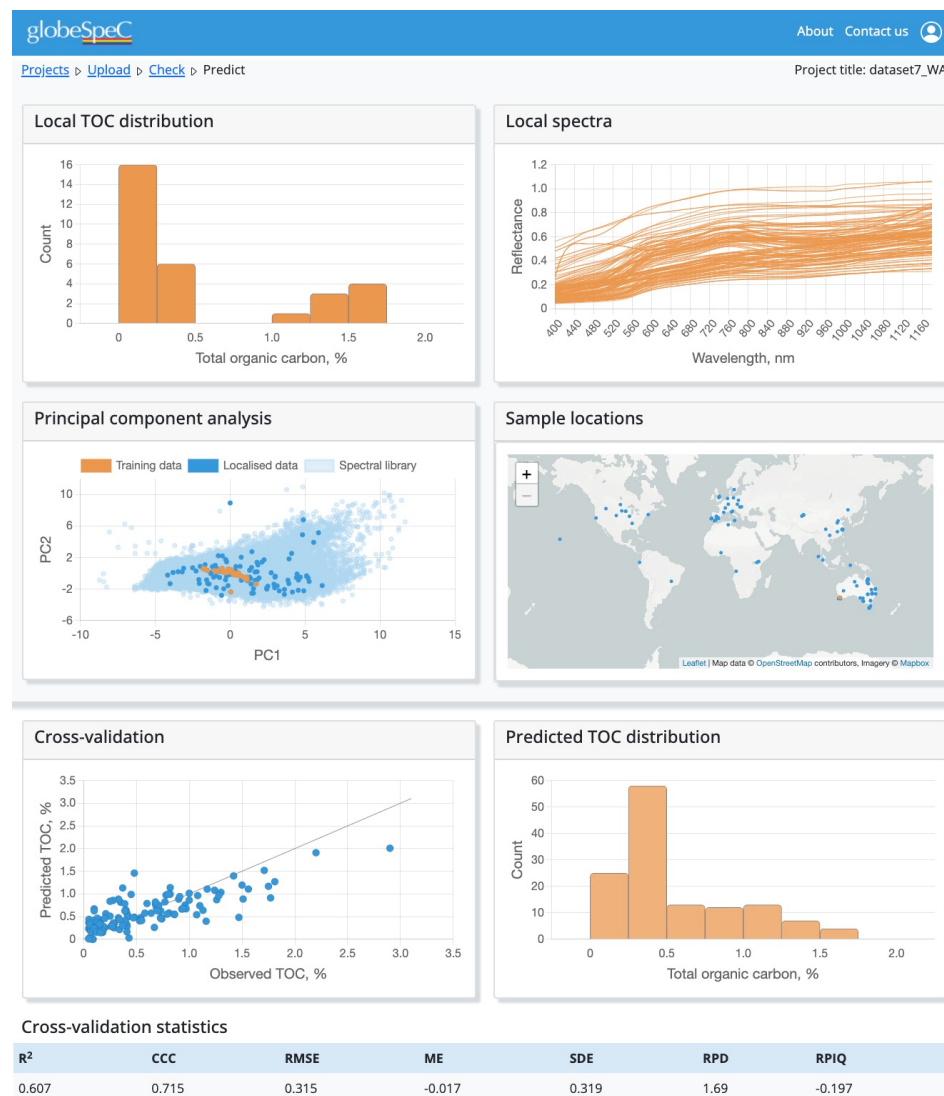
Example using USA data



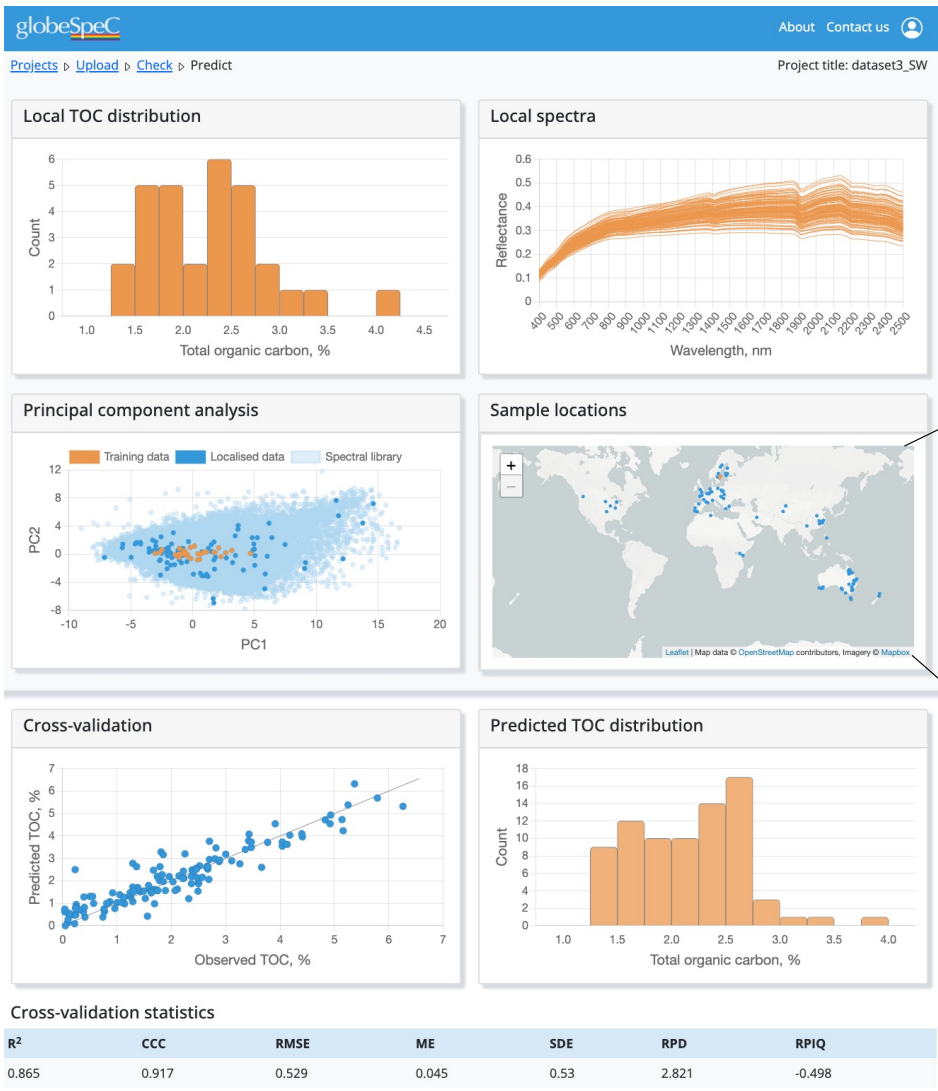
Example using Australian data

Can use spectra from different spectrometers as long as they are within the 350–2500 nm range (visible–near infrared).

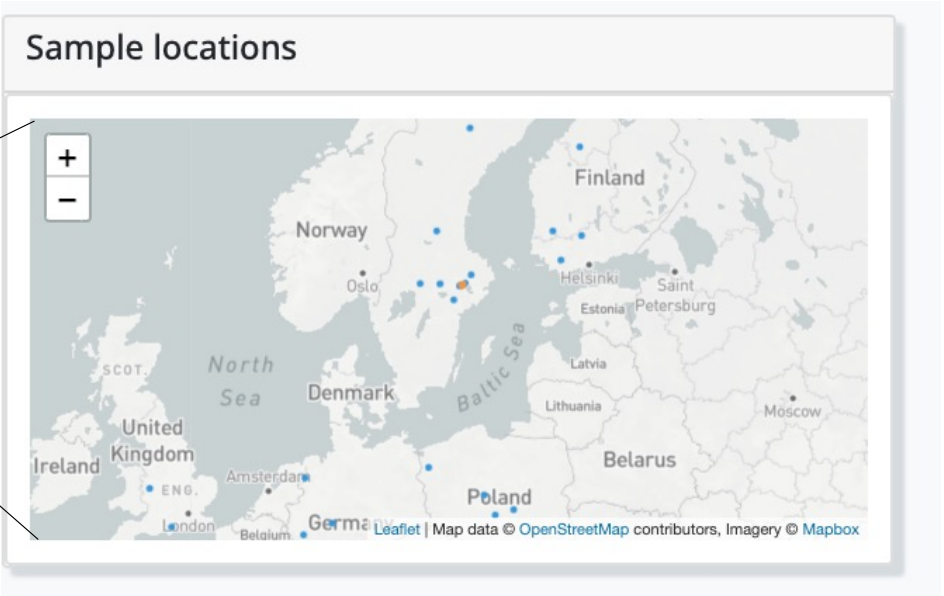
Next version will extend to also mid infrared (MIR).



This example uses spectra from 400–1160 nm



Example using Swedish data

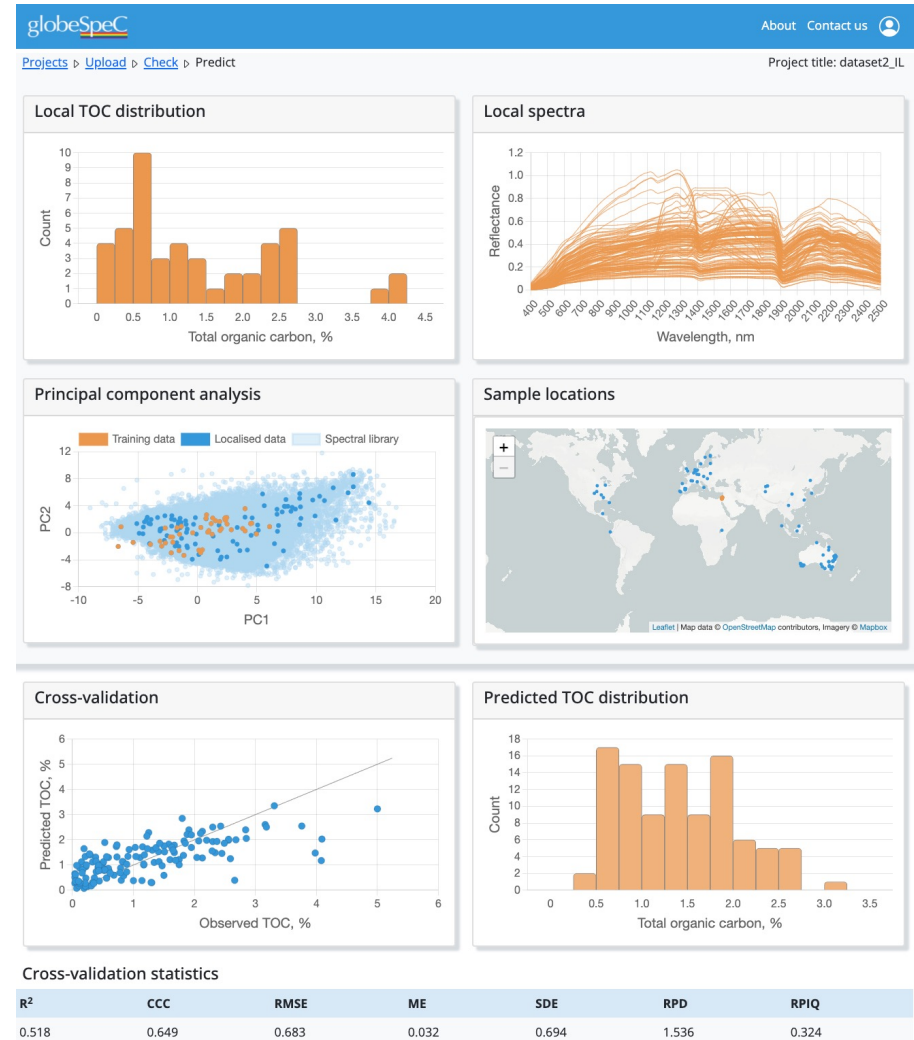


Interactive graphics

Example using data from Israel

Showing that the spectral library used here is lacking some similar samples to the ones from Israel

The larger and more diverse the spectral library, the better that **globeSpec** will predict.



Thank you.

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<http://curtin.edu/soil-landscape-sci>

