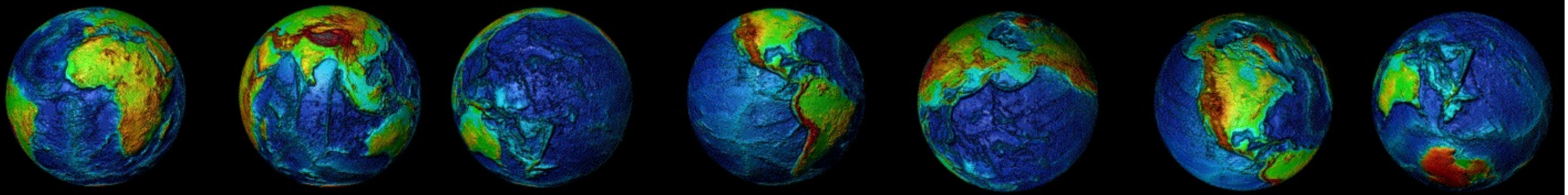
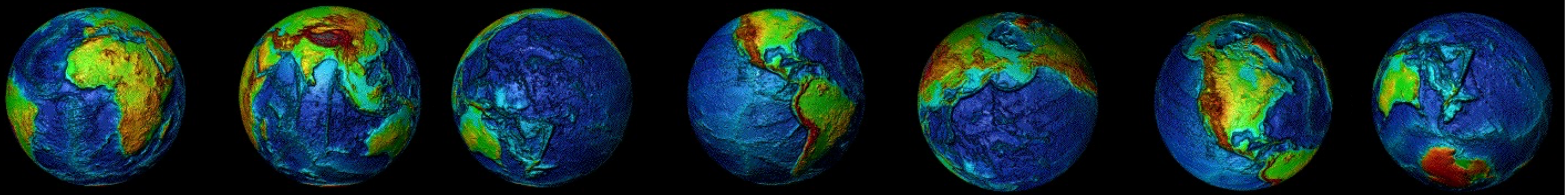


Global soil spectroscopy for the common good



Raphael VISCARRA ROSSEL
Soil & Landscape Science

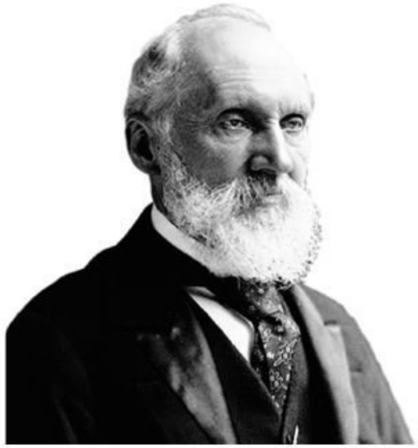
IEEE Standards Association
P4005 – Standards and protocols for soil spectroscopy

13 September 2021

soil & landscape science lab
Curtin University

Soil measurement and monitoring

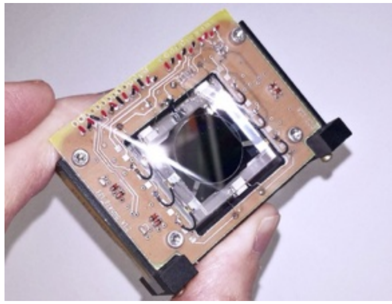
Effective decision-making relies on quantitative measurement and monitoring



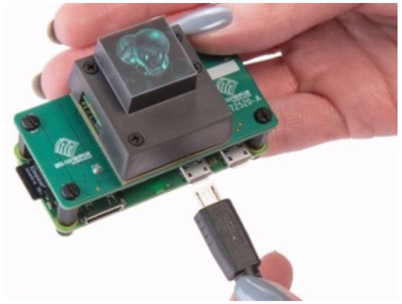
To measure
is to know.
If you can not
measure it,
you can not
Improve it.

~ Lord Kelvin

Significant technological and technical developments

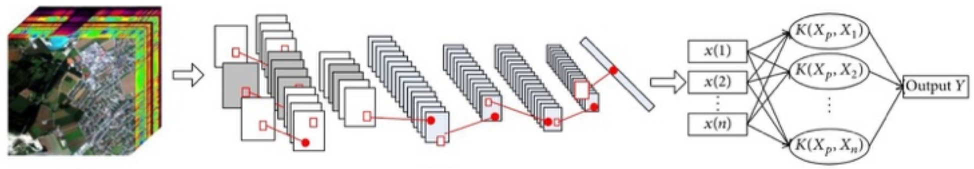


A Cubesat-sized hyperspectral imager from the VTT Technical Research Centre of Finland



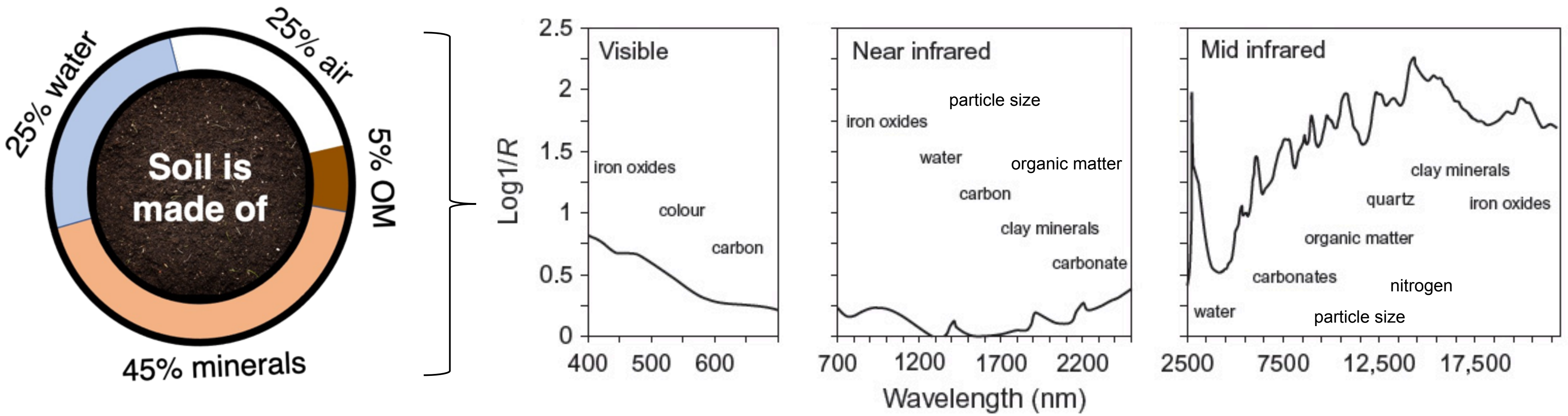
A MEMS spectrometer (1300–2600 nm) from NeoSpectra

Developments in data fusion with machine learning



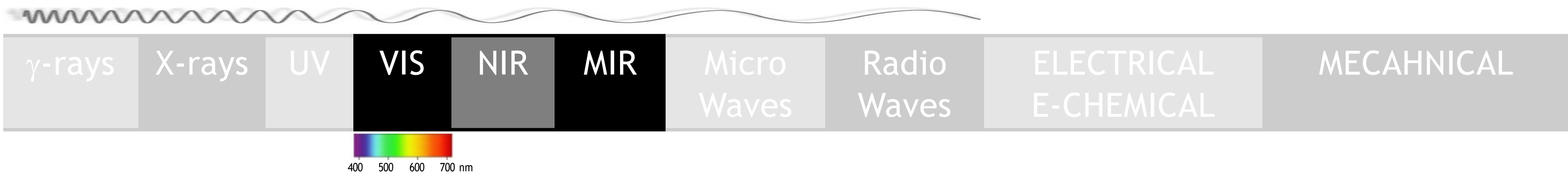
How might spectroscopy help?

Spectra measure the composition of soil which determines soil functions

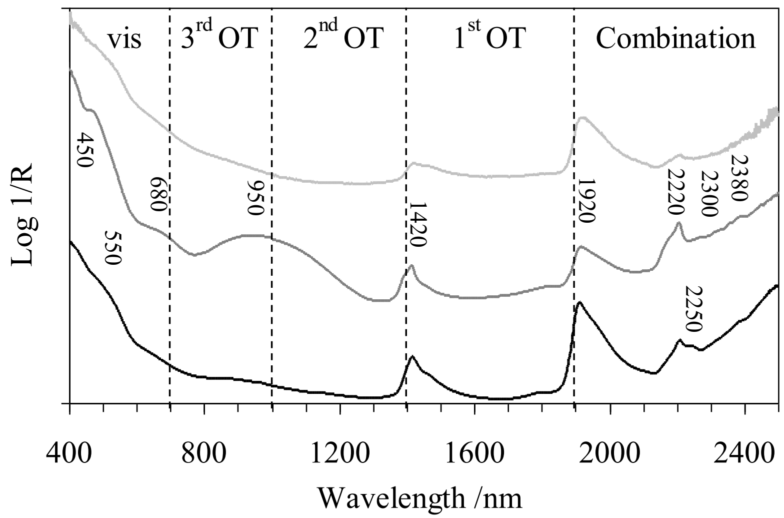


A single spectrum can effectively provide information on the soil and its properties

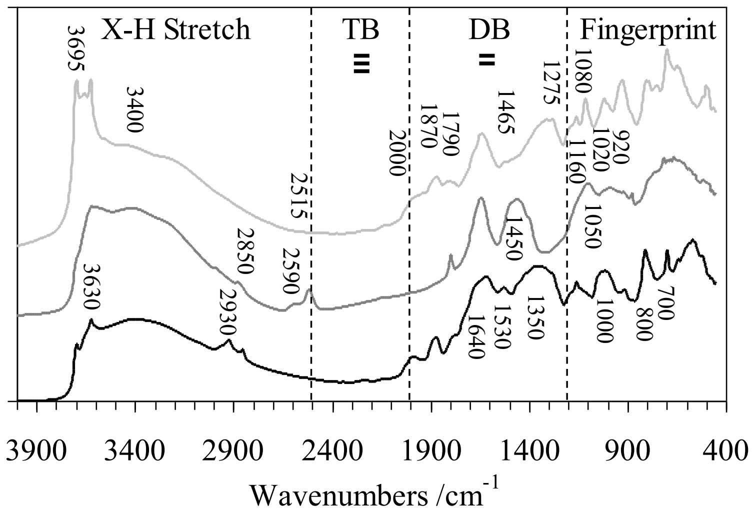
There is a fundamental physical process for soil spectroscopy



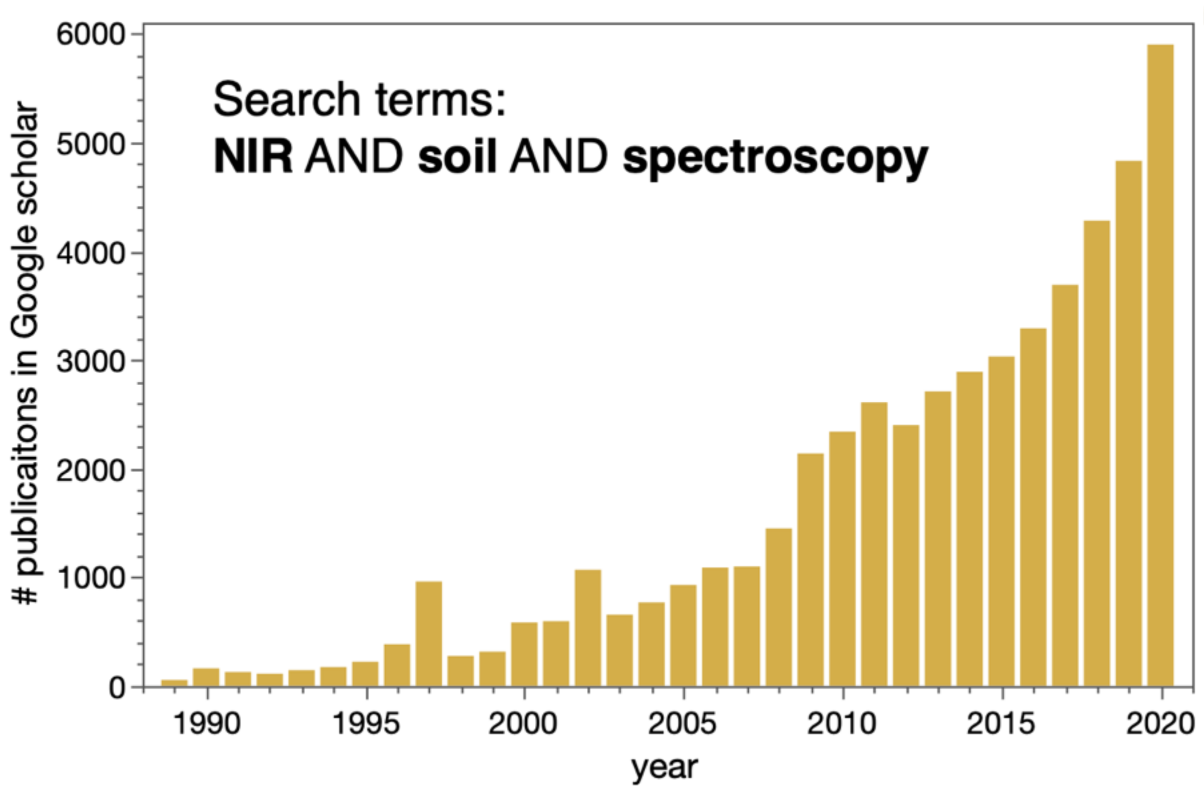
vis: electronic transitions
NIR: combinations and overtones



mid-IR: fundamental molecular vibrations of soil mineral and organic structures

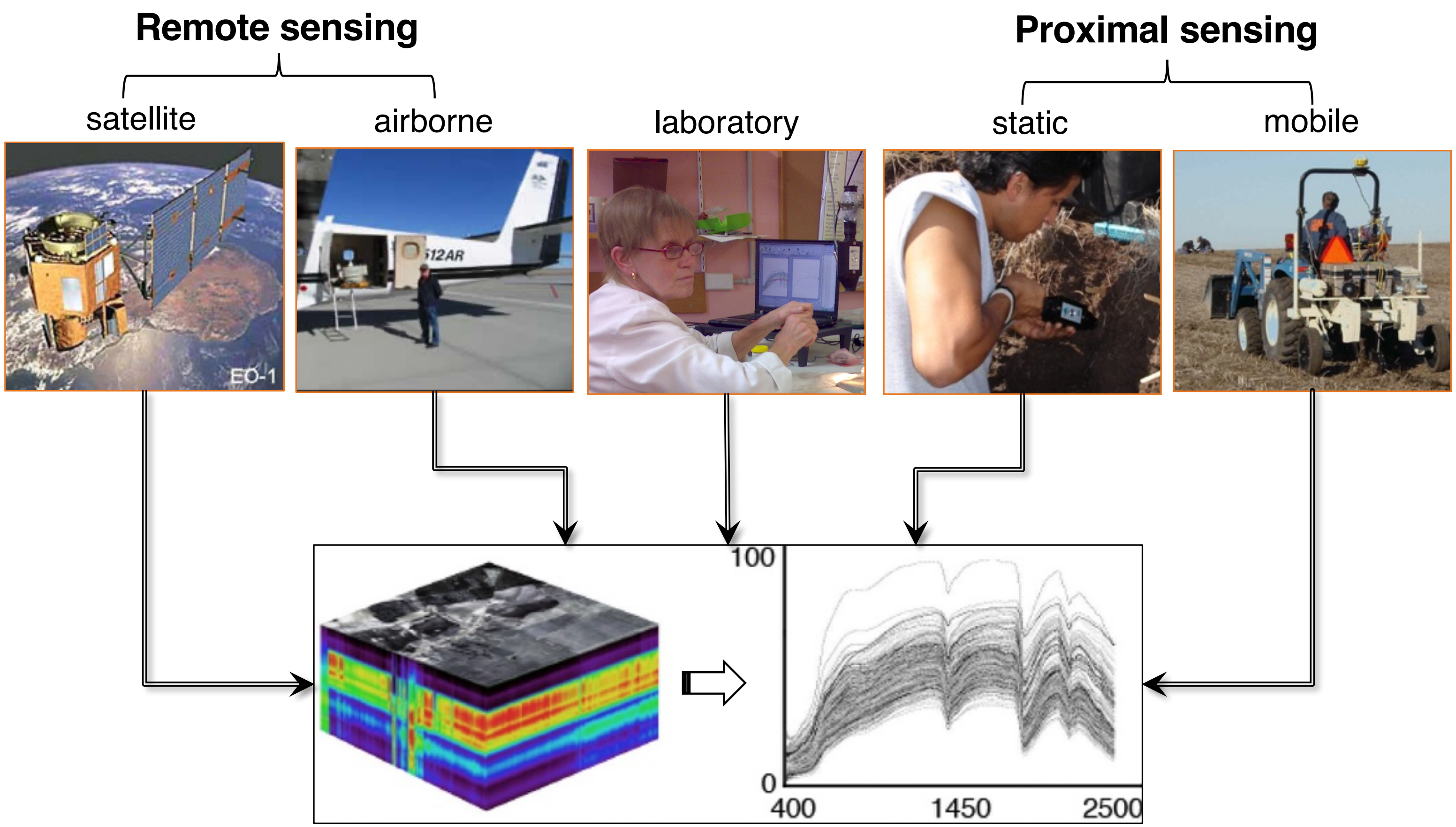


Soil spectroscopy research



Note: does not include visible or mid-IR spectroscopy

Spectra can be recorded from different platforms

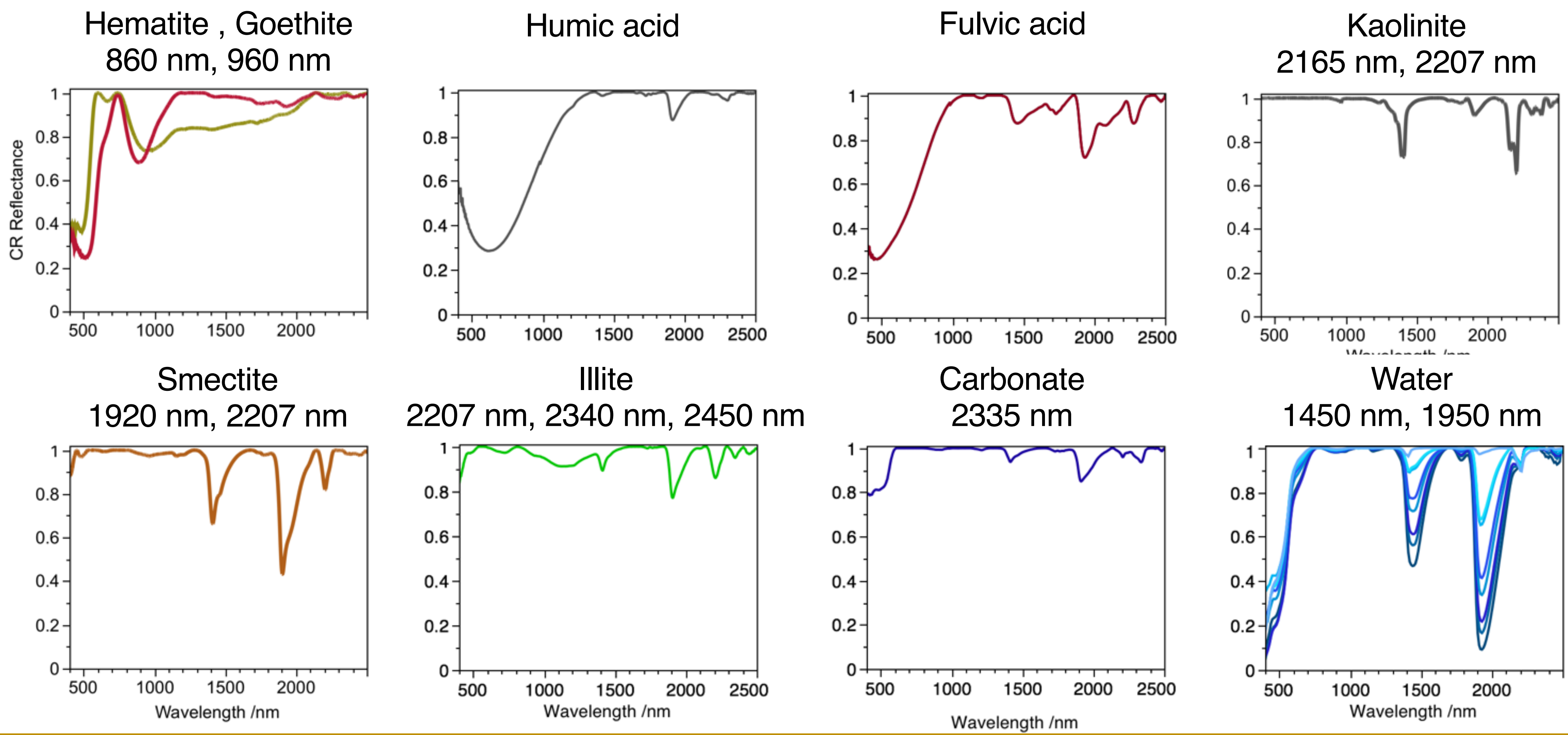


Decreasing cost and size of technologies

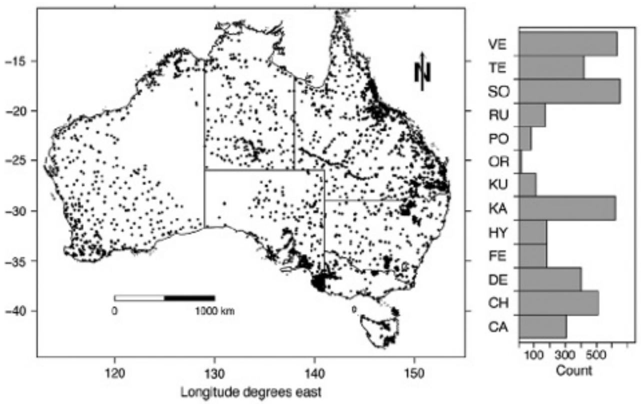
Sensors are becoming smaller, smarter, cheaper, faster, more energy efficient…

Examples of some applications

The soil information content of vis–NIR spectra

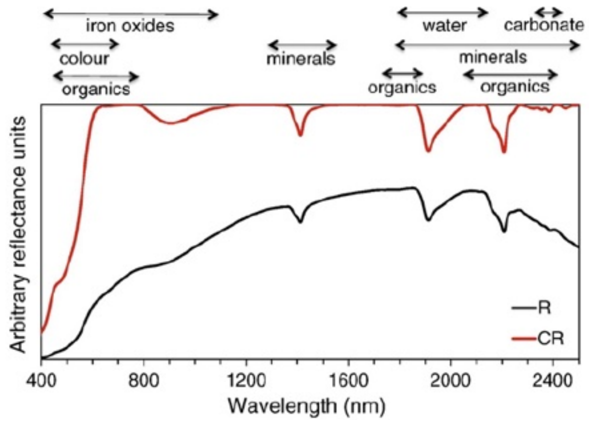


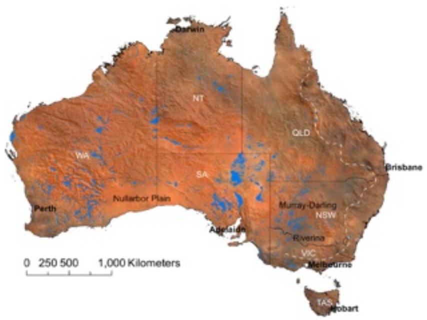
Specific wavelengths can be used for direct quantification



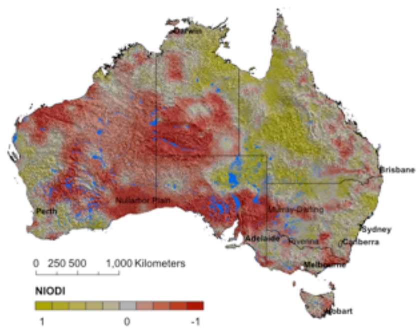
Measured vis–NIR spectra of 5,000+ archived representative soil samples from Australia

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

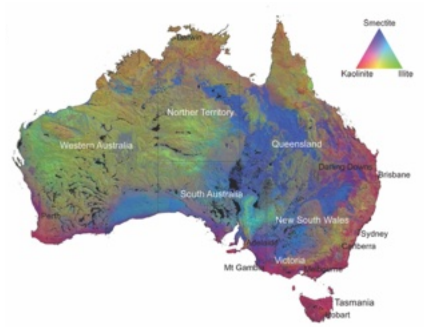




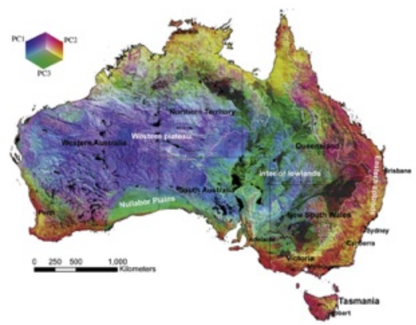
RGB composite but also maps of Munsell HVC



Probability of hematite or goethite

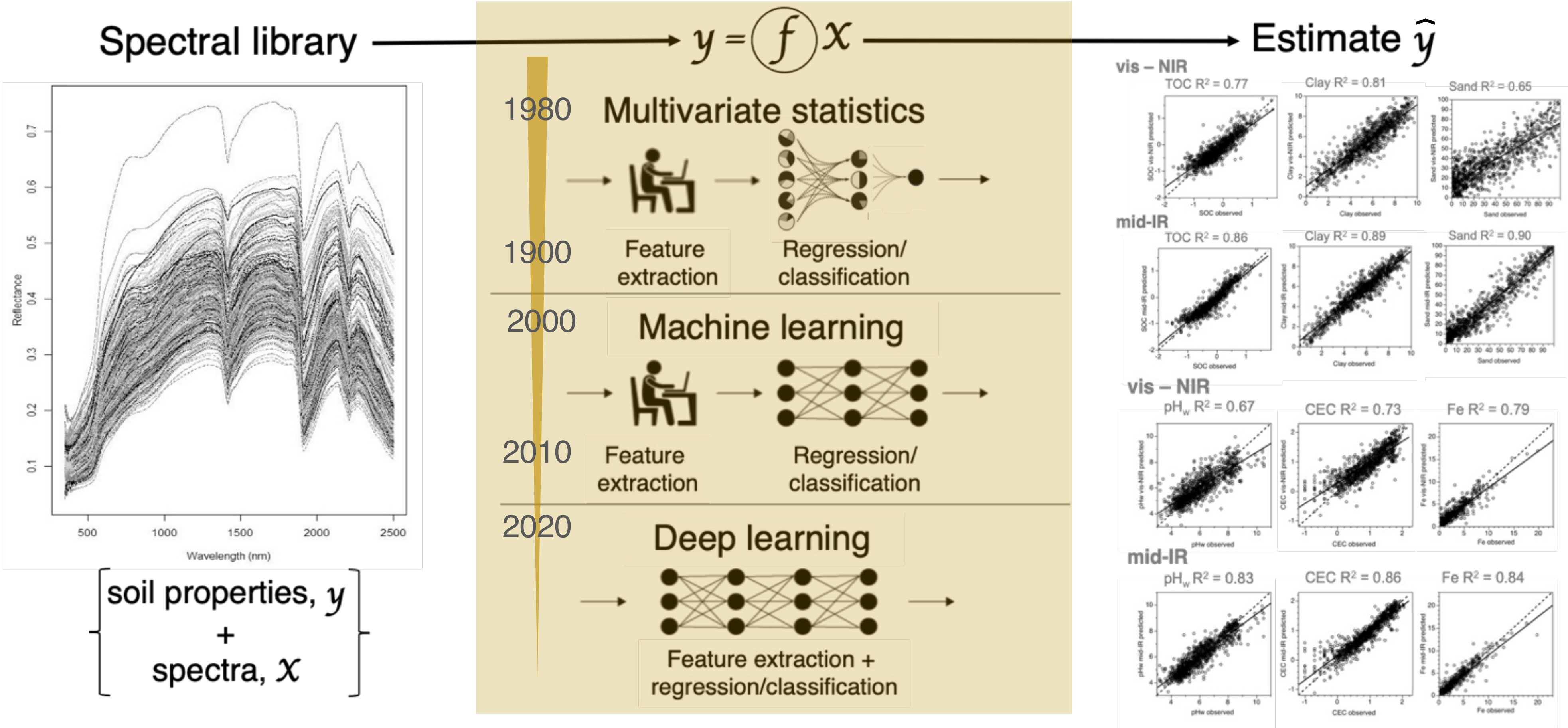


Maps of kaolinite illite, smectite 90 x 90 m



Proxy for soil type 90 x 90 m

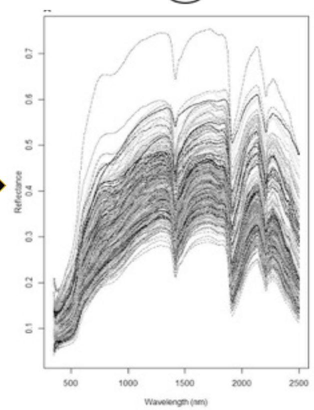
Soil properties can be modelled with spectra



Modelling requires spectral libraries

For example, the Australian spectral library

$y = f(x)$



- CSIRO's soil archive holds 50,000+ soil specimens from with an incomplete set of analytical data
- Measured 25,000+ soils with vis–NIR (& mid-IR)
- Spectroscopic modelling predicted soil attributes

Soil attribute	Mean	RMSE	SDE	ME	RPD
θ_{FC} /m^3 m^{-3}	0.32	0.06	0.06	−0.004	1.68
θ_{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
Log_{10}(Organic C)	-0.26	0.25	0.25	−0.01	2.17
Log_{10}(Total K)	-0.50	0.33	0.33	−0.04	1.87
Log_{10}(Total N)	-1.30	0.25	0.25	0.001	2.11
Log_{10}(C:N)	1.18	0.19	0.19	−0.001	1.40
Log_{10}(Total P)	-1.66	0.27	0.27	0.00	1.75
Log_{10}(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
CEC /cmol(+)kg^{-1}	15.6	7.08	7.06	0.51	2.13
Log_{10}(Exch. acidity)	0.42	0.28	0.28	0.009	1.49
Exch. Ca^{2+} /cmol(+)kg^{-1}	7.91	3.77	3.77	0.17	2.34
Log_{10}(Exch. K^{+})	-0.49	0.34	0.34	−0.02	1.65
Exch. Mg^{2+} /cmol(+)kg^{-1}	5.49	2.58	2.58	0.16	2.30
Log_{10}(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 Global Spectral Library project

The global soil spectral library

Development initiated in 2008 in response to large interest by soil scientists and in response to potential 'stagnation' of research.

Voluntary project with 3 main aims:

- Establish a 'community of practice' for soil spectroscopy
- Investigate the global spectra and demonstrate its value
- Develop a web portal to enable use of the global library

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A global spectral library to characterize the world's soil

CrossMark

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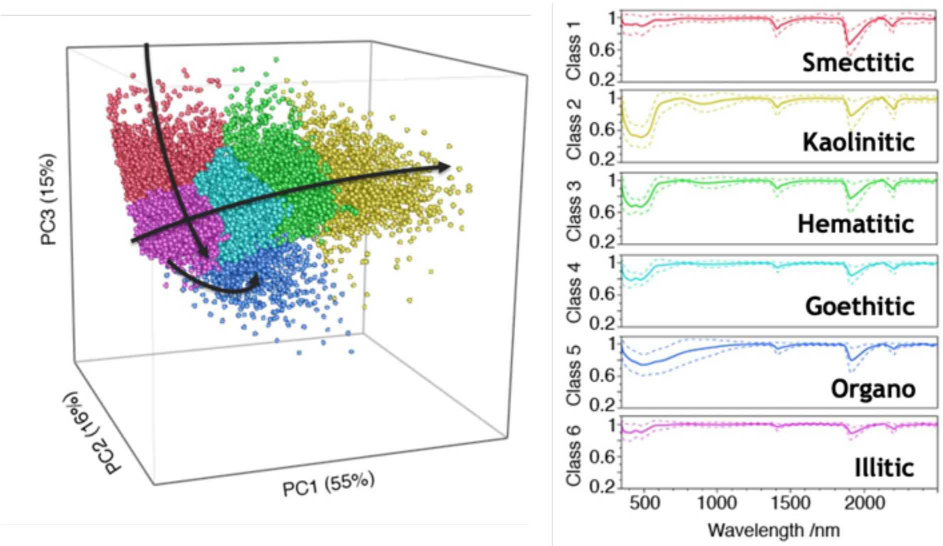
Oceania	
Raphael Viscarra Rossel	AUSTRALIA
Carolyn Hedley, Bambang Kusumo	NEW ZEALAND
Antarctica	
Carolyn Hedley, Pierre Roudier	ROSS DEPENDENCY
Other from ICRAF	
ISRIC	OTHER COUNTRIES

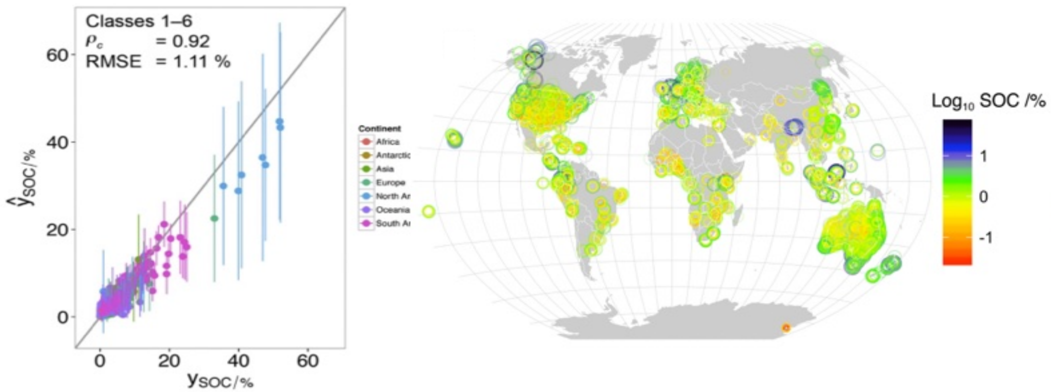
Summary of some results from the initial analysis

The soil information content of the global spectra showing weathering and mineral-organic sequences



(c-means classification of PCs)

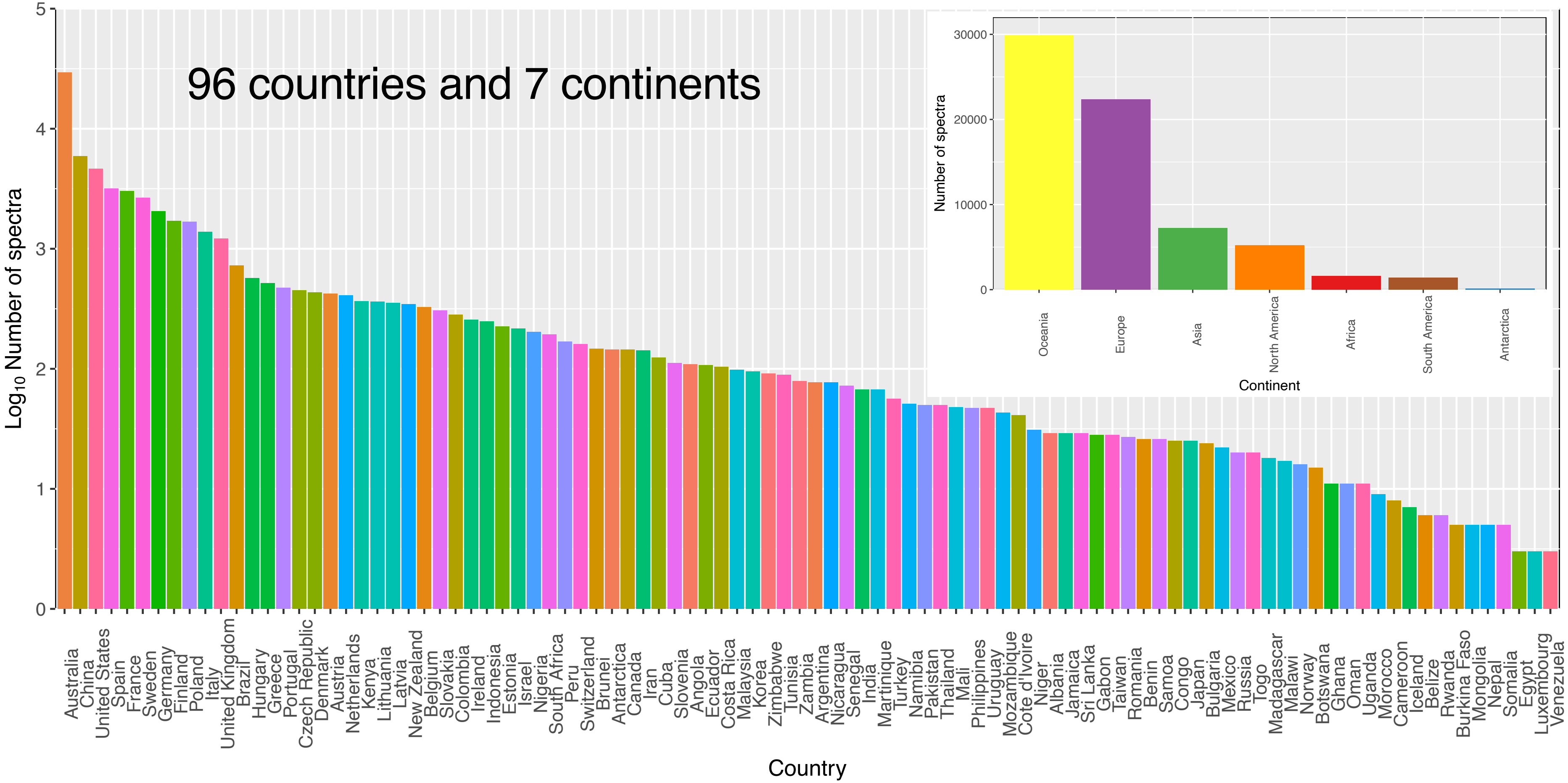
Global modelling with regression trees: Cubist



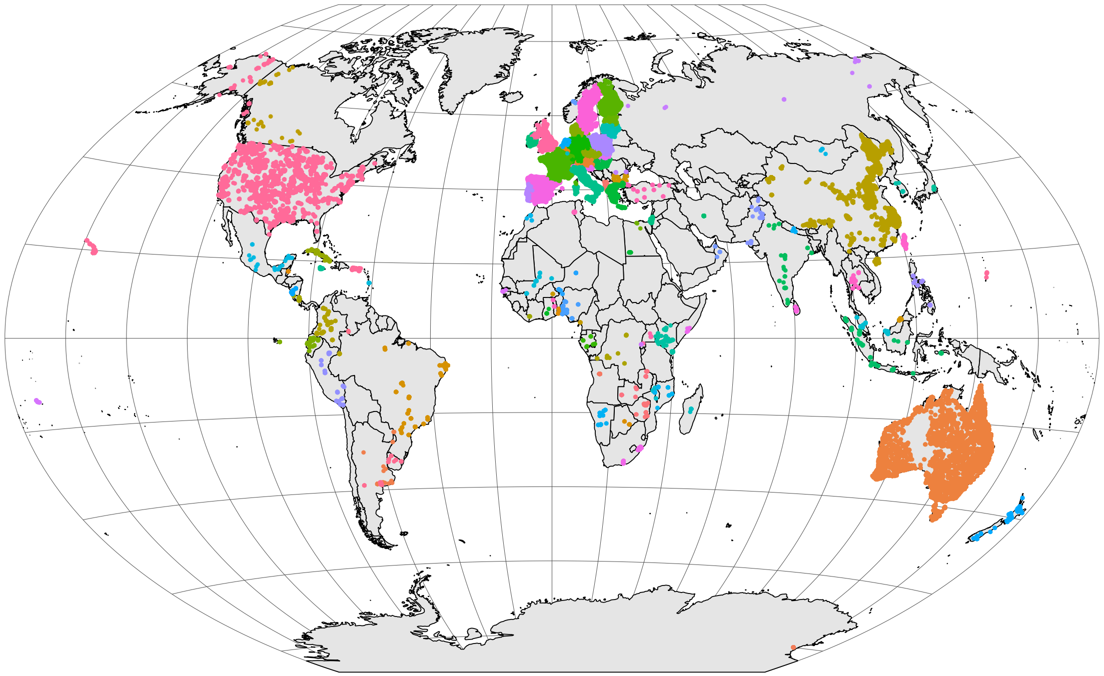
Accurate global models for SOC, SIC, clay, pH CEC, Fe, Silt (ρ_c = 0.75–0.92)

Less accurate global models for sand (ρ_c = 0.67)

An update on the current state



An update on the current state



Recent new contributions from:

Czechia – Asa Gholizadeh, Lubos Borivka

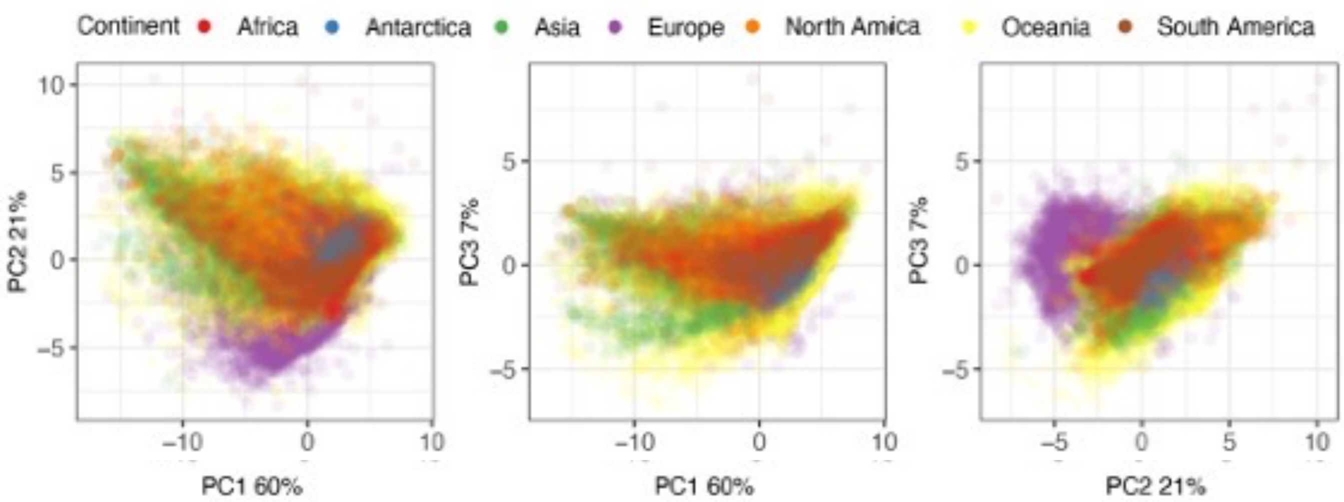
Canada – Mevin St Luce

USA – Ken Suduth

Sweden – Johanna Wetterlind

Total number of spectra 67,811, from around 38,000 unique sites

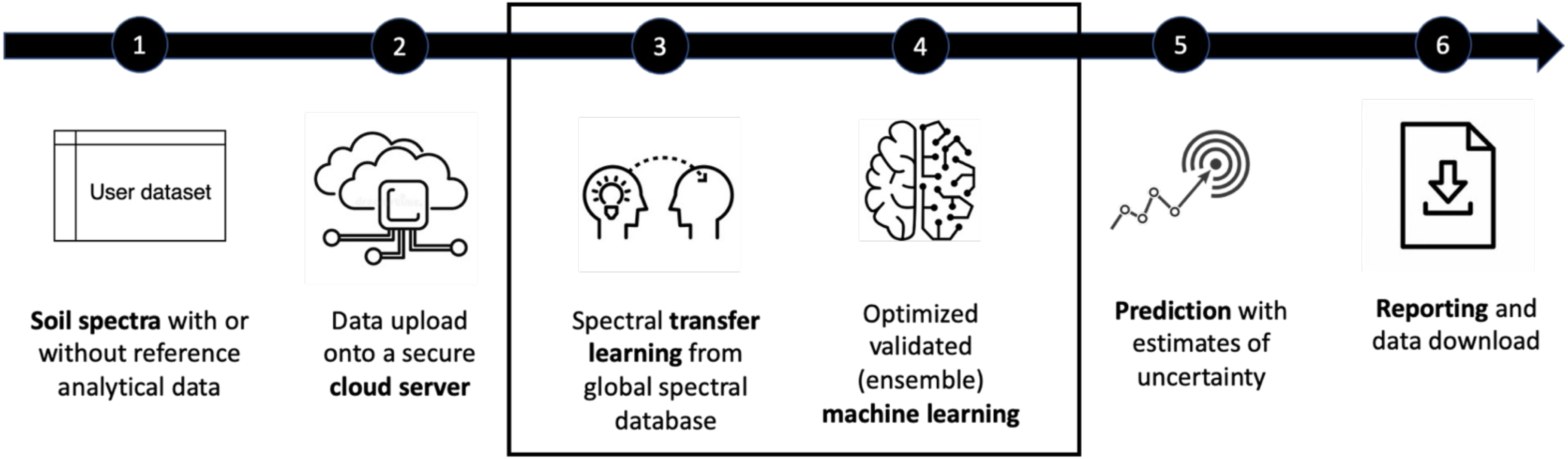
Visualising the spectra with PCA



Mathematical standardization of the spectra produced consistent data for modelling

The next phase of the global project

Develop a web portal to enable use of the global library for the common good



Complexity hidden from the user but performed using robust scientific peer reviewed methods

Thank you.

Raphael Viscarra Rossel

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