FAO Webinar: Soil data and informtaion

2nd October 2024

Assessing Soil indicators using Spectroscopy for Soil Security

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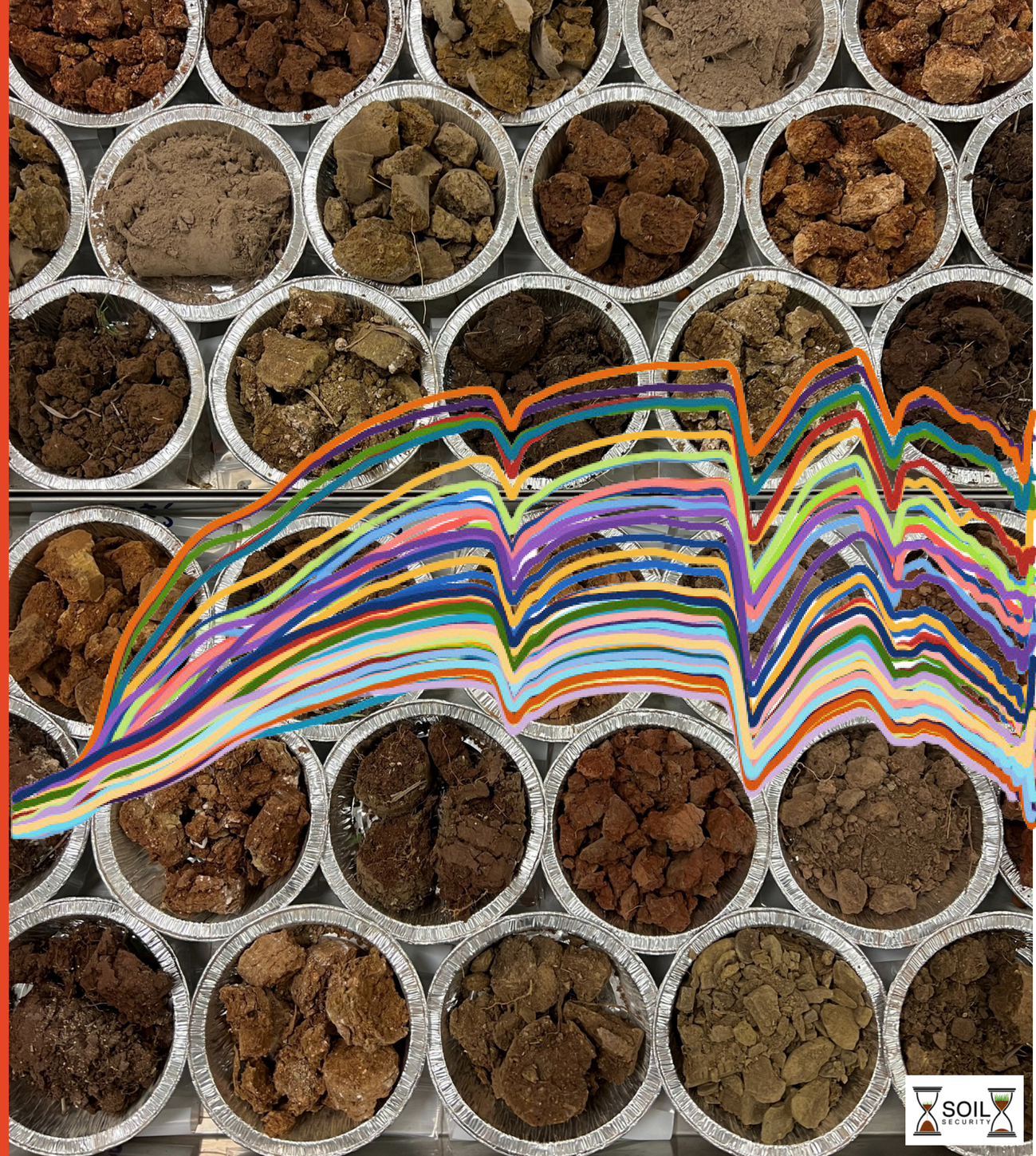
THE UNIVERSITY OF SYDNEY



Spectral Instruments

X-ray Fluorescence (XRF)

0.01-10 nm

Laser Induced Spectroscopy (LIBS)

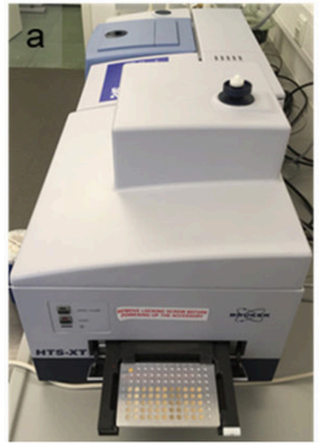
200 – 1000 nm

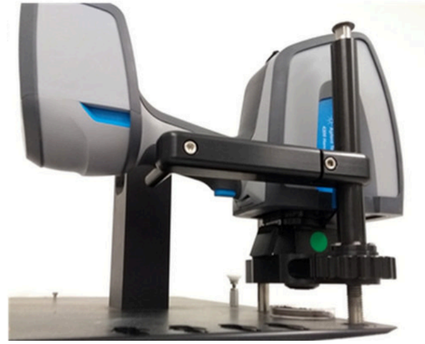
Visible Near Infrared (Vis-NIR)

400 – 2500 nm

Mid Infrared (MIR)

2500 – 25000 nm





Spectral Instruments

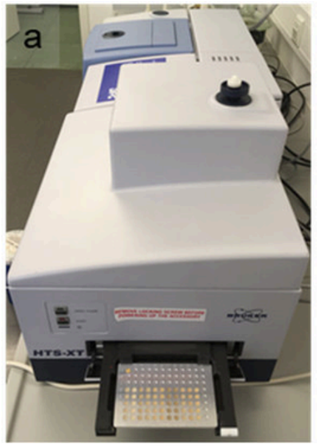
Most used ⟵ ⟶ **Least used**

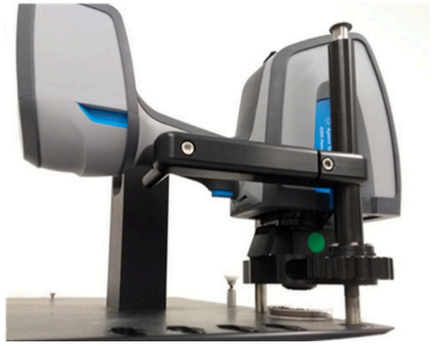
Visible Near Infrared (Vis-NIR)

400 – 2500 nm

Mid Infrared (MIR)

2500 – 25000 nm





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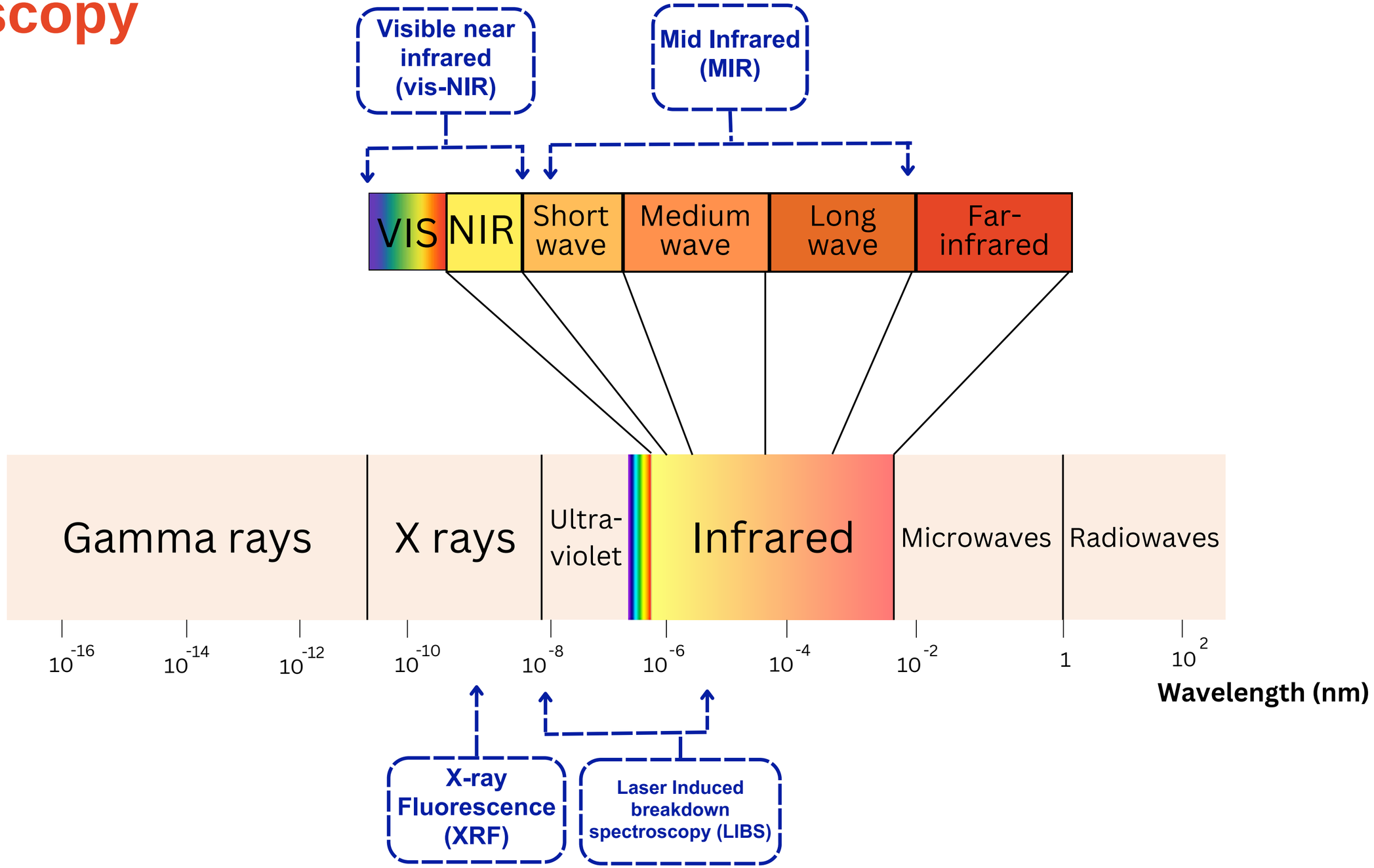
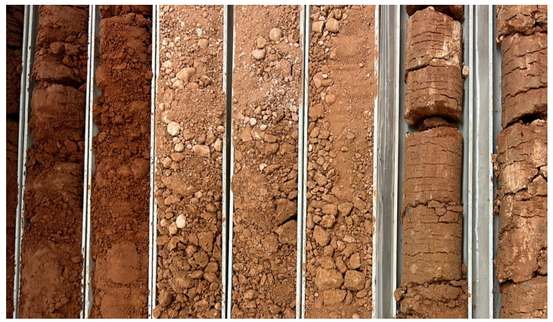
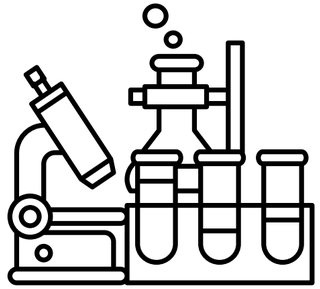
Spectroscopy



Workflow of spectroscopy in soil science



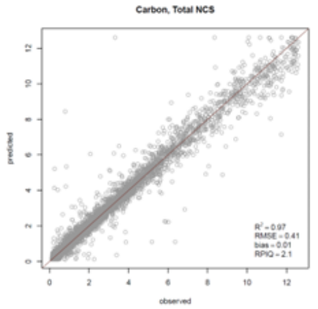
Soil sample



Lab analysis

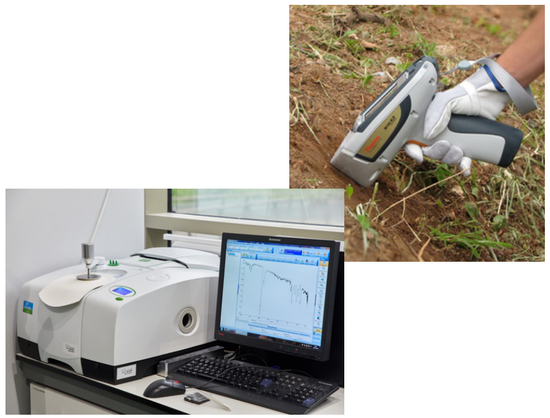
Calibration Functions

Partial Least Squares Regression
Cubist
Random Forest
Neural Network
Deep Learning



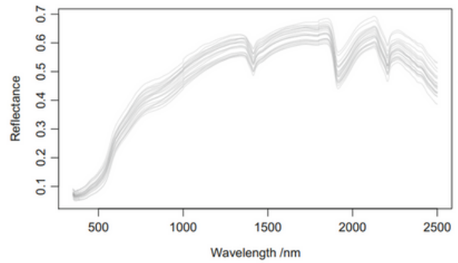
Predicted properties

OC
AWC
CEC
Sand



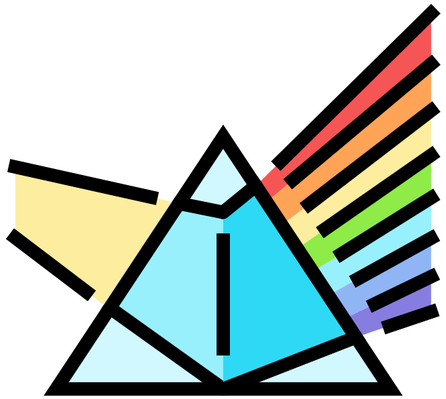
Spectra collection

In field or lab



Spectra & spectral libraries

Spectroscopy

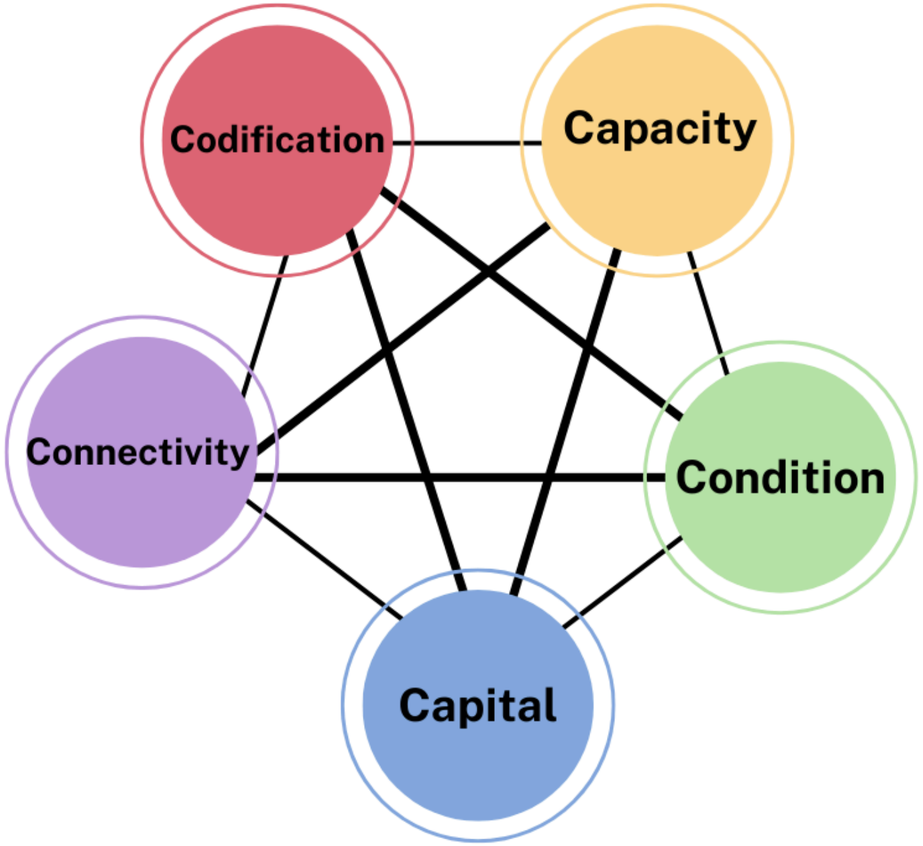


Advantages

- Minimal sample preparation required
- Estimates multiple properties, simultaneously
- Time efficient
- Cost efficient
- Reproducible

SOIL SECURITY

Dimensions



Roles

Soil Functions

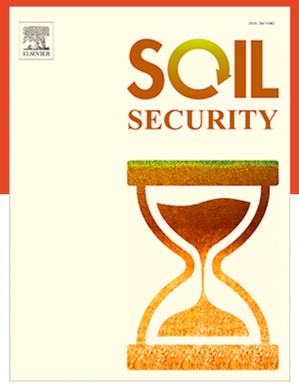
- Archive for artefacts
- Biomass production
- Carbon storage
- Contaminants filter & remediator
- Habitat for biodiversity
- Nutrient store & regulator
- Source of raw materials**
- Water store & regulator

Soil Services

- Climate change mitigation
- Biodiversity protecting
- Ecosystem maintaining
- Energy securing
- Food & nutrition securing
- Human health
- Water securing

Threats to Soil

- Acidification
- Contamination
- Decarbonisation
- Erosion
- Salinisation
- Soil sealing
- Structural decline
- Habitat loss



Soil Security Assessment Framework:

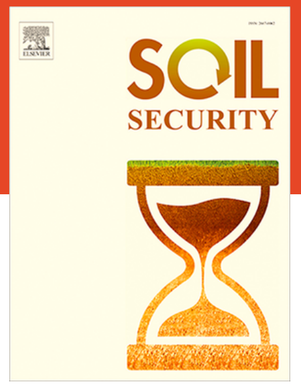
Systematic Evaluation of soils

Dimensions

Roles	Capacity	Condition	Capital	Connectivity	Codification
Functions					
Services					
Resilience to Threats					

Evangelista, S.J., Field, D.J., McBratney, A.B., Minasny, B., Ng, W., Padarian, J., Dobarco, M.R. and Wadoux, A.M.C., 2023. A proposal for the assessment of soil security: soil functions, soil services and threats to soil. Soil Security, 10, p.100086.

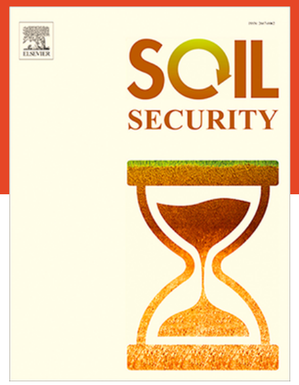
(McBratney et. al. 2014)



Biophysical dimensions

Roles	Capacity	Condition
Functions	8	8
Services	7	7
Resilience to Threats	8	8

46 potential evaluations via spectroscopy



Capacity

Condition

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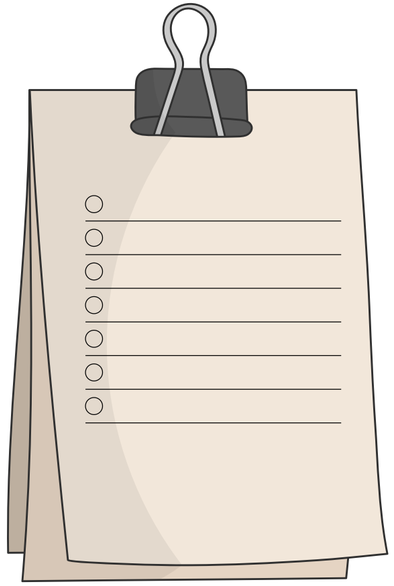
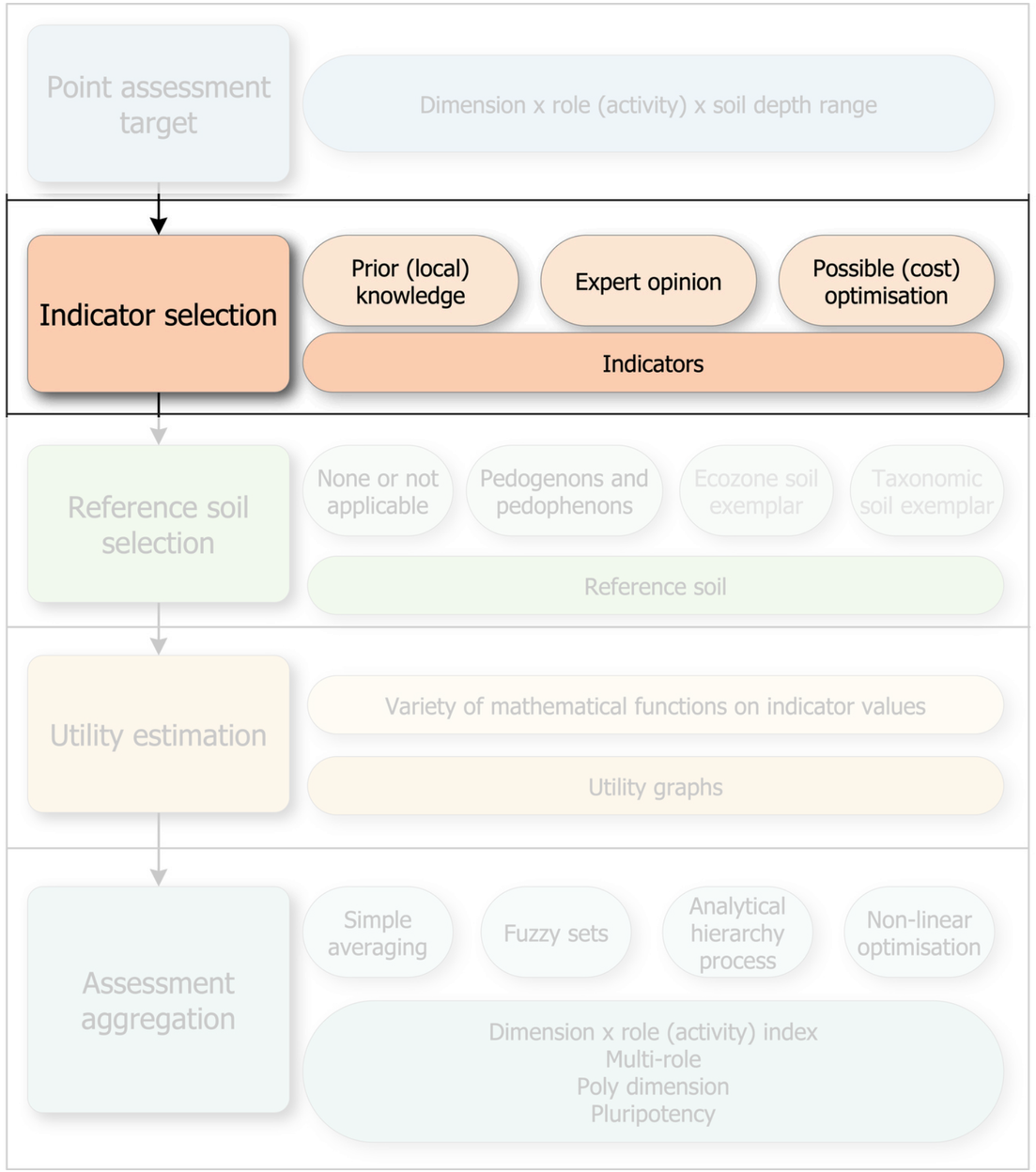
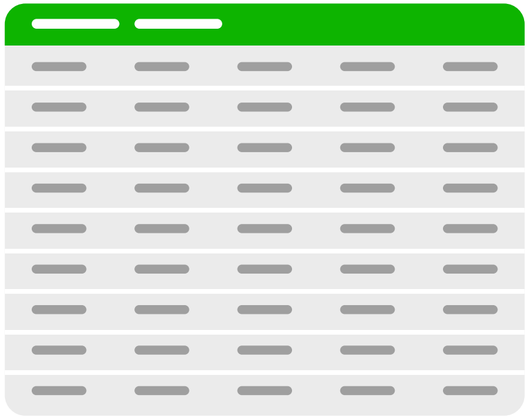


~43 *potential* soil indicators listed (so far)



Indicator Selection

- Expert opinion
- Not exhaustive
- Indicative
- Data availability
- Pragmatic
- Surrogates



Indicators

Role: Functions	Capacity	Condition
A producer of food and biomass	AWC; clay; silt; sand; CEC	Carbon; AWC; Bulk density; biodiversity; pH; EC
A store of carbon	Carbon; MAOC	OC; OC:Clay ratio
A store and regulator of nutrients	Clay; CEC; Mineral type	OC; AWC; pH; Microbial abundance
A purifier and regulator of water	Clay; AWC	AWC; OC; Ksat; denitrification capacity; nutrient sorption capacity
A habitat for, and of, biodiversity	Biodiversity; pHBC	Microbial abundance; biodiversity; pH
A filter and remediator of contaminants	CEC; Mineral type; Redox Poise; deep drainage	Biochar; Microbial abundance
A source of raw materials **	Clay, sand and stone content; thickness of peat layer; depth to bedrock	Bulk density; OC
An archive or archaeological artefacts	pHBC; Redox Poise; specific heat capacity	pH; soil temperature; Redox potential

(Evangelista et. al 2023)

Indicators

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Archive for artefacts	pHBC; Redox Poise; specific heat capacity	pH; soil temperature; Redox potential

(Evangelista et. al 2023)

INDICATOR	Subcategory of role in each dimensions		SPECTRAL INSTRUMENT			
	Capacity	Condition	**Vis-NIR**	**MIR**	**XRF**	**LIBS**
Cation Exchange Capacity (CEC)	A producer of food and biomass (F) A store and regulator of nutrients (F) A filter and remediator of contaminants (F) **Food and nutrition securing (S)** **Contamination (T)**					

(F) = Functions, (S) = Services, (T) = Threats to soil

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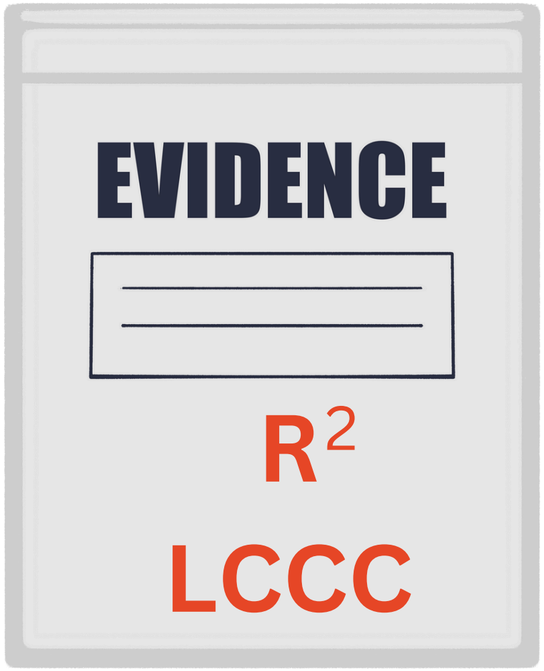
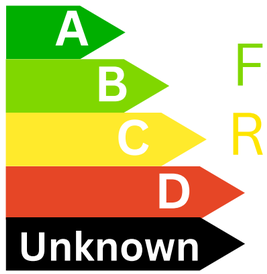
(F) = Functions, (S) = Services, (T) = Threats to soil

How well is it estimated?



Average of the performance accuracies reported



Classification

Well estimated

Fairly well estimated

Reasonably estimated

Poorly estimated

Unknown

Ng, W., Minasny, B., Jeon, S. H., & McBratney, A. (2022). Mid-infrared spectroscopy for accurate measurement of an extensive set of soil properties for assessing soil functions. Soil Security, 6, 100043.

INDICATOR	Subcategory of role in each dimensions		SPECTRAL INSTRUMENT			
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Cation Exchange Capacity (CEC)	A producer of food and biomass (F) A store and regulator of nutrients (F) A filter and remediator of contaminants (F) **Food and nutrition securing (S)** **Contamination (T)**		Fair (B)	Fair (B)	Reasonable (C)	Fair (B)

(F) = Functions, (S) = Services, (T) = Threats to soil

INDICATOR	Subcategory of role in each dimensions		SPECTRAL INSTRUMENTS PERFORMANCE ACCURACY			
	Capacity	Condition	Vis-NIR	MIR	XRF	LIBS
Total carbon content	A store of carbon (F) A store and regulator of nutrients (F) Climate change mitigation (S) Water securing (S) Decarbonisation (T) Habitat loss/ degradation (T)	A producer of food and biomass (F) Climate change mitigation (S) Decarbonisation (T) Soil structural decline (T)	Well (A)	Well (A)	Fair (B)	Fair (B)
Organic carbon	Energy securing (S)	A purifier and regulator of water (F) A store of carbon (F) A store and regulator of nutrients (F) A source of raw materials (F) Environmental maintaining (S) Water securing (S)	Well (A)	Well (A)	Reasonable (C)	Fair (B)
pH	Energy securing (S)	A producer of food and biomass (F) A store and regulator of nutrients (F) A habitat for and of biodiversity (F) An archive of archaeological artefacts (F) Environmental maintaining (S) Biodiversity protecting (S) Food and nutrition securing (S) Acidification (T) Contamination (T)	Reasonable (C)	Fair (B)	Reasonable (C)	Fair (B)

(F) = Functions, (S) = Services, (T) = Threats to soil

INDICATOR	Subcategory of role in each dimensions		SPECTRAL INSTRUMENTS PERFORMANCE ACCURACY			
	Capacity	Condition	Vis-NIR	MIR	XRF	LIBS
Electric conductivity (EC)	Salinisation (T)	A producer of food and biomass (F) Food and nutrition securing (S) Salinisation (T)	Poor (D)	Poor (D)	Reasonable (C)	Reasonable (C)
Bulk density	Accelerated erosion (T)	A producer of food and biomass (F) A source of raw materials (F) Water securing (S) Food and nutrition securing (S) Energy securing (S)	Reasonable (C)	Reasonable (C)	Poor (D)	Unknown
Microbial Biomass		A store and regulator of nutrients (F) A habitat for and of biodiversity (F)	Fair (B)	Fair (B)	Reasonable (C)	Poor (D)
Phospholipid fatty acid (PLFA Concentration)	A habitat for and of biodiversity (F) Contamination (T)	A producer of food and biomass (F) A habitat for and of biodiversity (F) Biodiversity protecting (S) Contamination (T)	Reasonable (C)	Fair (B)	Unknown	Unknown

(F) = Functions, (S) = Services, (T) = Threats to soil

Full table to be published....

To summarise

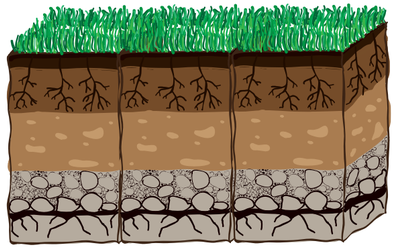
Indicators
Well estimated
Classified as ‘A’

vis-NIR
Total carbon content
Inorganic carbon
Pyrolytic carbon
Respiration rate

MIR
Total carbon content
Inorganic carbon
Pyrolytic carbon
Mineral types (some)
Macronutrients (some)
Potentially toxic elements (some)
Porosity
Shear strength
Coefficient of linear extensibility (COLE)
AWC
Respiration rate

XRF
Mineral types (some)
Macronutrients (some)
Potentially toxic elements (some)
Respiration rate

LIBS
Macronutrients (some)
Potentially toxic elements (some)
Shear strength



To summarise

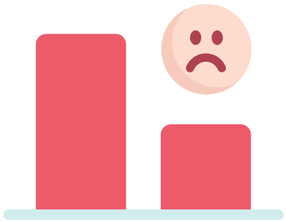
Indicators
Poorly estimated
Classified as ‘D’

vis-NIR
Micronutrients (some)
Macronutrients (some)
Potentially toxic elements (some)
MAOC
POC
EC
Porosity
Soil structure
Hydraulic conductivity

MIR
Mineral type (some)
Micronutrients (some)
Macronutrients (some)
Hydraulic conductivity

XRF
Mineral types (some)
Micronutrients (some)
Macronutrients (some)
Potentially toxic elements (some)
Bulk density

LIBS
Macronutrients (some)
Soil structure
Aggregate stability (slaking)
Microbial biomass



Soil indicators with no evidence found

“Unknown” - Reports not found
Across all instruments

Redox Potential

Redox buffering capacity

Denitrification capacity

Tensile strength

Adsorption isotherms

Rootable soil depth

Deep drainage

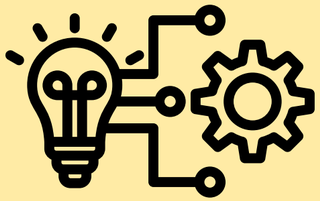
INDICATOR	Subcategory of role in each dimensions		SPECTRAL INSTRUMENTS			
	Capacity	Condition	**Vis-NIR**	**MIR**	**XRF**	**LIBS**
Redox potential		A store and regulator of nutrients (F) An archive of archaeological artefacts (F)	Unknown	Unknown	Unknown	Unknown
Redox buffering capacity	A filter and remediator of contaminants (F) An Archive of archaeological artefacts (F) Habitat loss/degradation (T)		Unknown	Unknown	Unknown	Unknown
Tensile strength	Accelerated erosion (T)	A producer of food and biomass (F) A source of raw materials (F) Water securing (S) Food and nutrition securing (S) Energy securing (S)	Unknown	Unknown	Unknown	Unknown

(F) = Functions, (S) = Services, (T) = Threats to soil

Evolution

Pedotransfer functions

A set of functions that can be used to predict a property or properties from other soil properties



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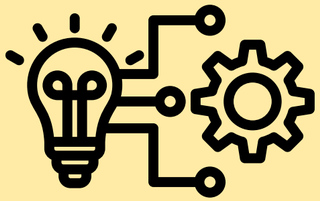


Soil spectral inference

Predicting soil properties from
a spectrum or spectra **(direct)**
OR
predicted by predicted soil properties**(indirect)**

Soil spectral inference

Predicting soil properties from

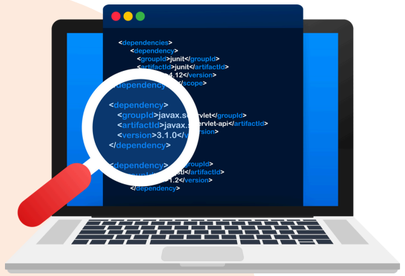
a spectrum or spectra **(direct)**

OR

predicted by predicted soil properties**(indirect)**

SINFERS

Soil **INFER**ence **S**ystem



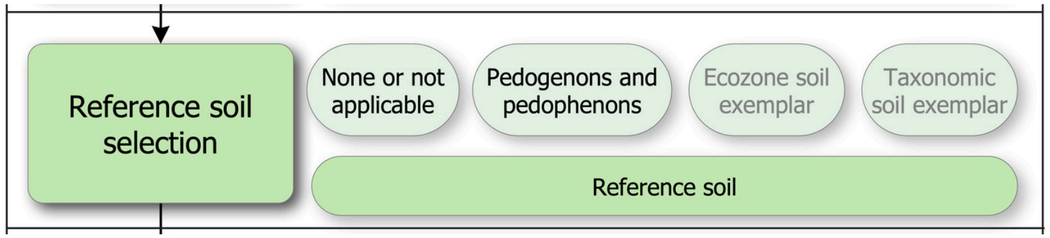
Software engine for the systematic prediction of soil properties from other soil properties using existing PTF's

A FUTURE FOR SOIL SPECTRAL INFERENCE

Webinar #3 2021

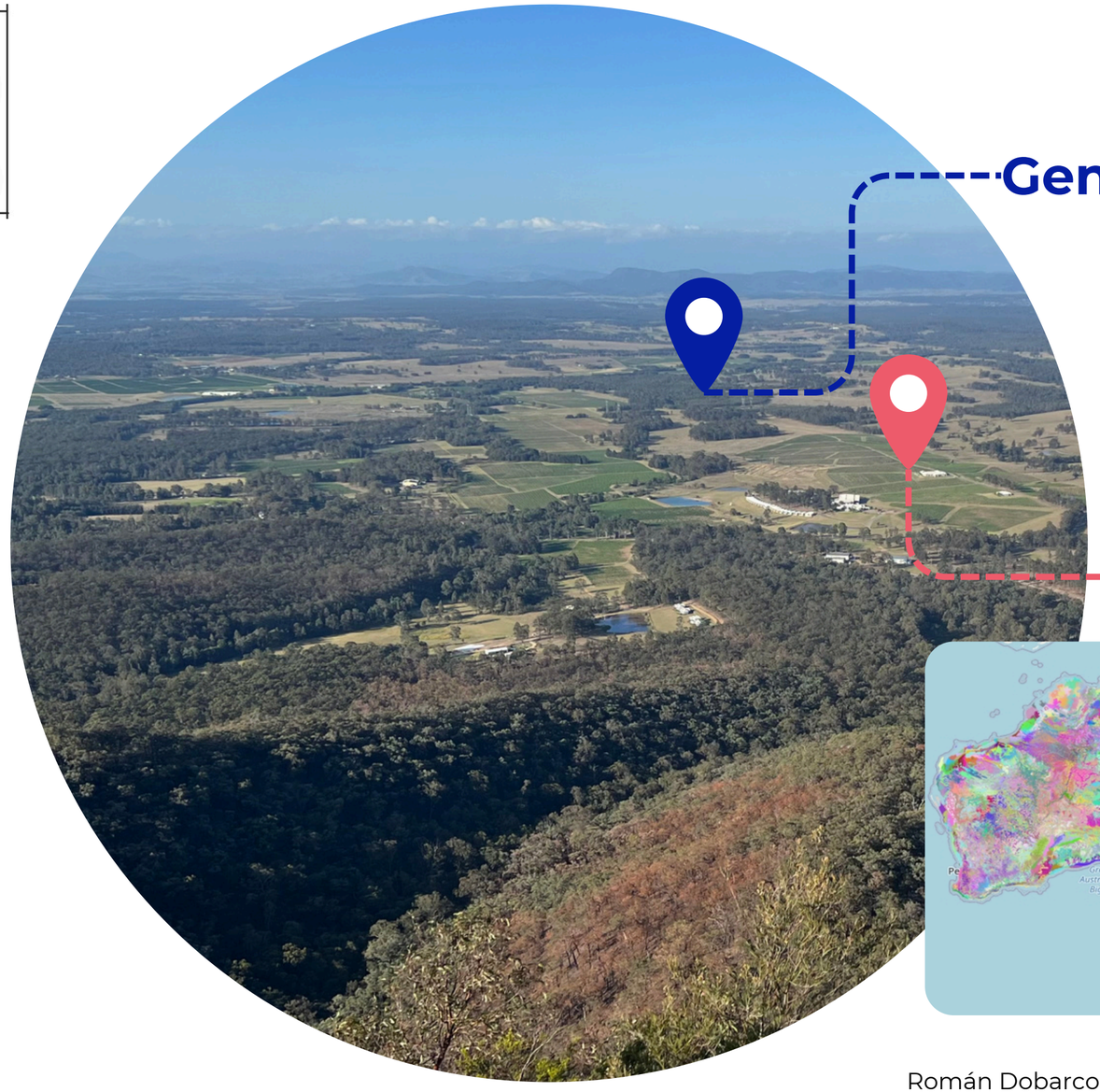
GLOSOLAN
Soil spectroscopy
training workshops

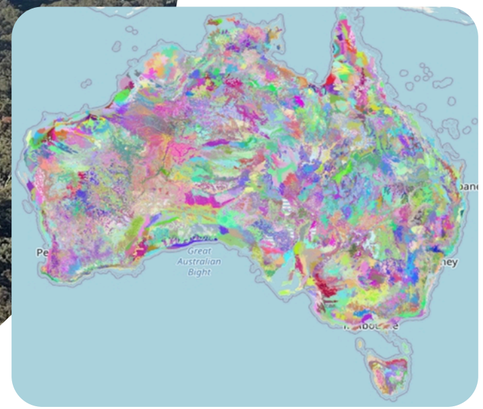
Reference soil selection



Pedogenons are soils developed under similar soil forming factors

> *Genosoil* = Least disturbed
> *Phenosoil* = Modified from human impact



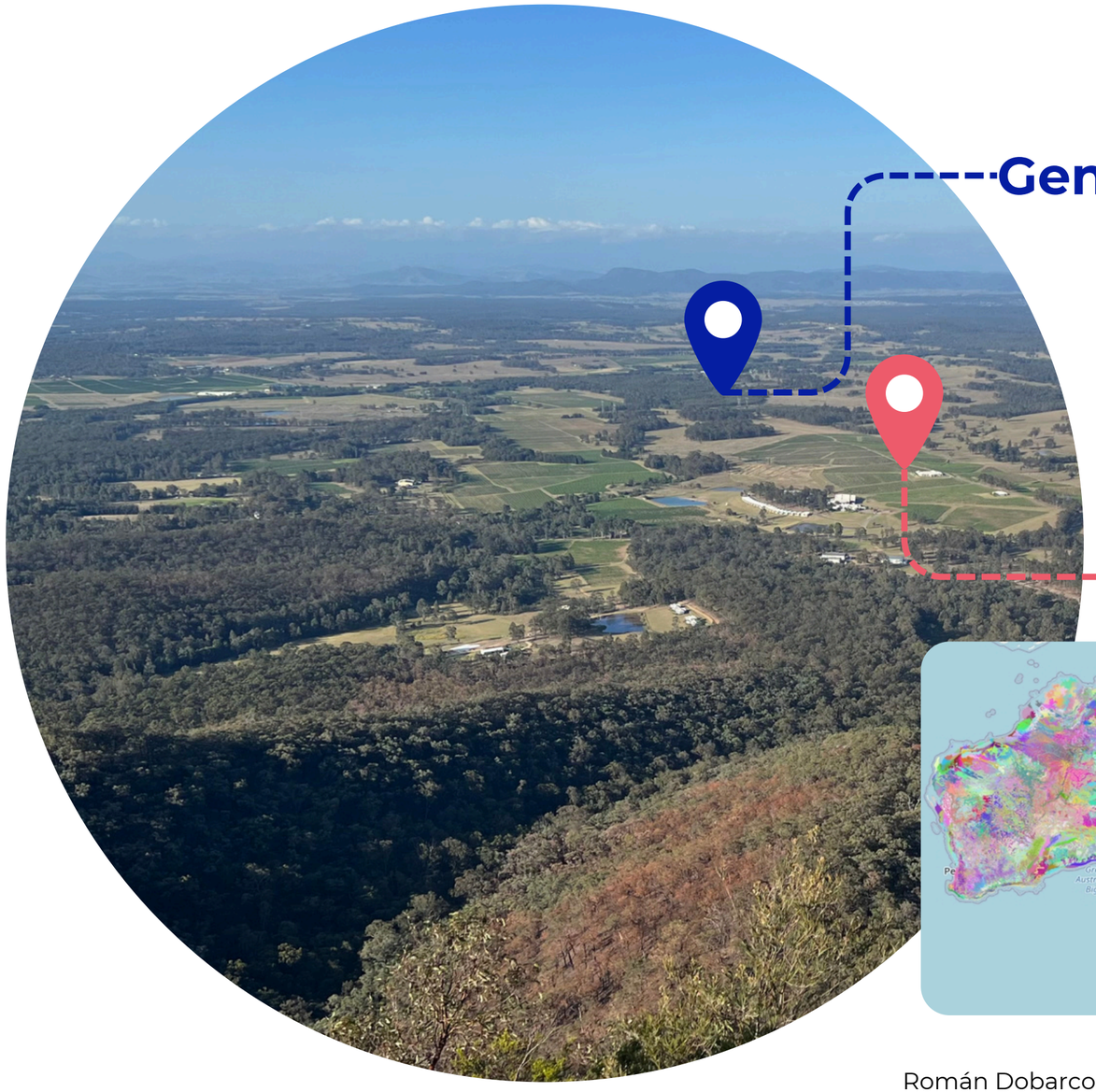


Román Dobarco et. al (2021) *Geoderma*

Reference soil selection

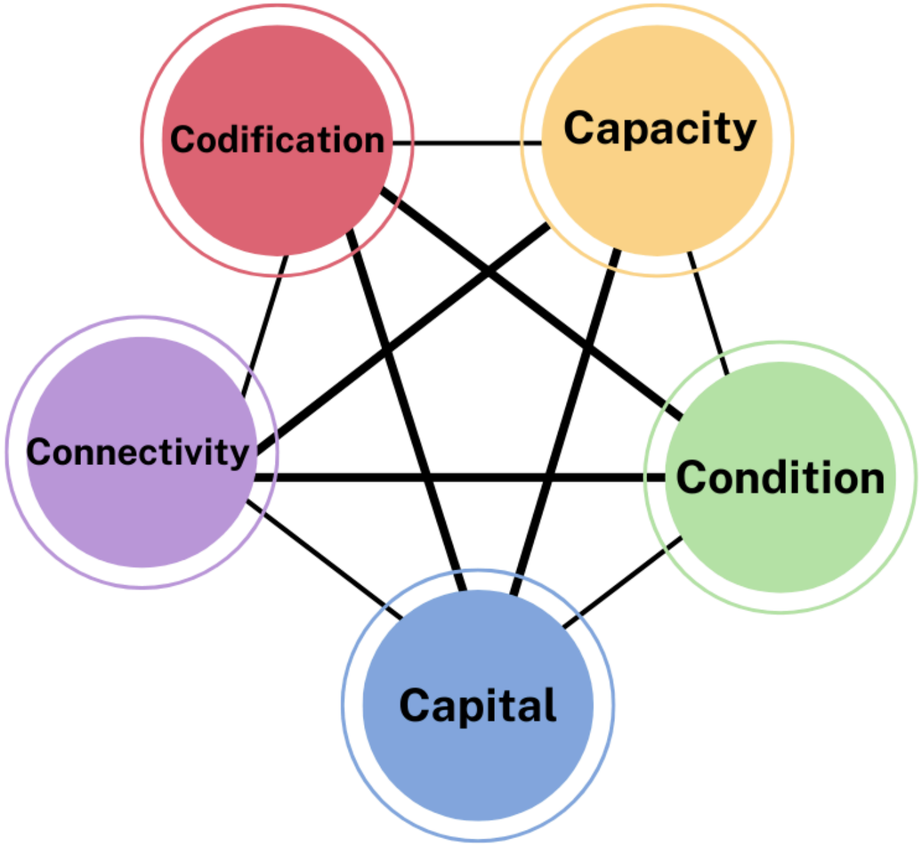
Spectroscopy can enable the observation of

soil change



Román Dobarco et. al (2021) *Geoderma*

Future of Spectroscopy IN SOIL SECURITY



01

Spectroscopy for other dimensions

Can we use spectroscopy for indirectly measuring any of the indicators for socioeconomic dimensions?

e.g. Capital - carbon stocks (onset or offset)

Future of Spectroscopy
IN SOIL SECURITY

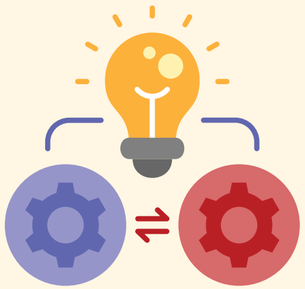
01 Spectroscopy for other dimensions

Can we use spectroscopy for indirectly measuring any of the indicators for socioeconomic dimensions?

e.g. Capital - carbon stocks (onset or offset)

02 Combining spectra analysers

Combining spectral data to gain complementary features and improve assessments



Conclusions

- Spectroscopy is an efficient way to estimate soil properties for soil security assessments of Capacity and Condition

- Promising for overall soil security assessment

Conclusions

- Several properties remain un-investigated

Conclusions

- Important for monitoring soil condition [health] and soil capacity [quality]
- Contribute to inform national and global agendas - Important for policy development

Thank you!

Q A

Acknowledgement

We acknowledge the support of the Australian Research Council Laureate Fellowship (FL210100054) on Soil Security entitled *'A calculable approach to securing Australia's soil'*

Special thanks to:

Amin Sharififar

Nicolas Francos

Thank you to:

Alex McBratney
Budiman Minasny
Wartini Ng

THE UNIVERSITY OF SYDNEY

Australian Government
Australian Research Council