Rapid and cost-effective soil analysis utilizing IR technology

Pacific Soils: Final Review
(Objective 3.2)

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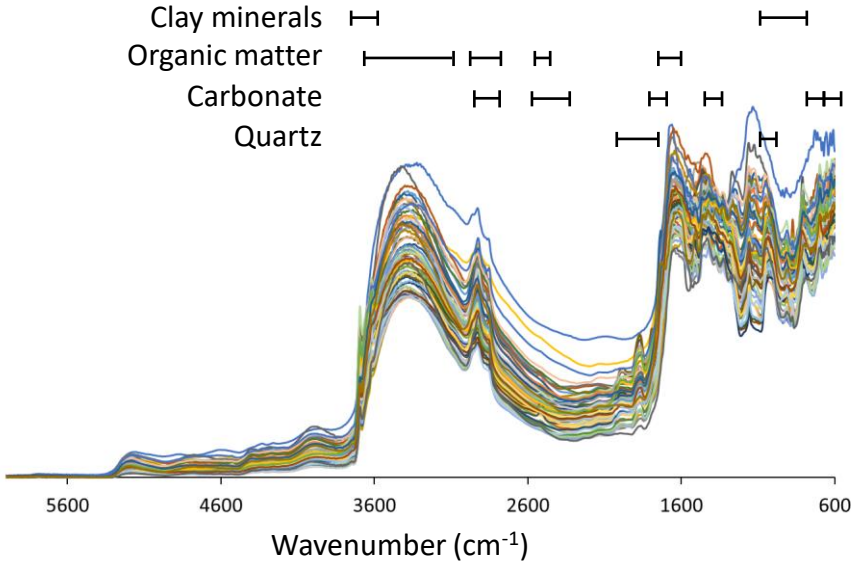
Brief introduction to IR spectroscopy

- Differentiates based on energy required to induce vibrations in covalent bonds
- Organic and mineral components are observed



Important note: IR does not define molecular composition

Graph courtesy of Jeff Baldock, CSIRO

Where our journey started

Research question

- What soil sampling, **testing** and interpretation protocols should be used on different soil types across the Pacific?

Objective

- Utilise **MIR technology** to make **rapid assessment** of calcareous and volcanic **soil fertility**
  - Introduce soil sample processing, measurement and soil spectral inference, and QC analysis protocols at FACL, MOA
  - Test MIR spectroscopy for estimating PICTs soil properties of agronomic importance
  - Populate pilot calibration datasets for forming the basis for rapid estimation of PICTs soils fertility status using MIR technology

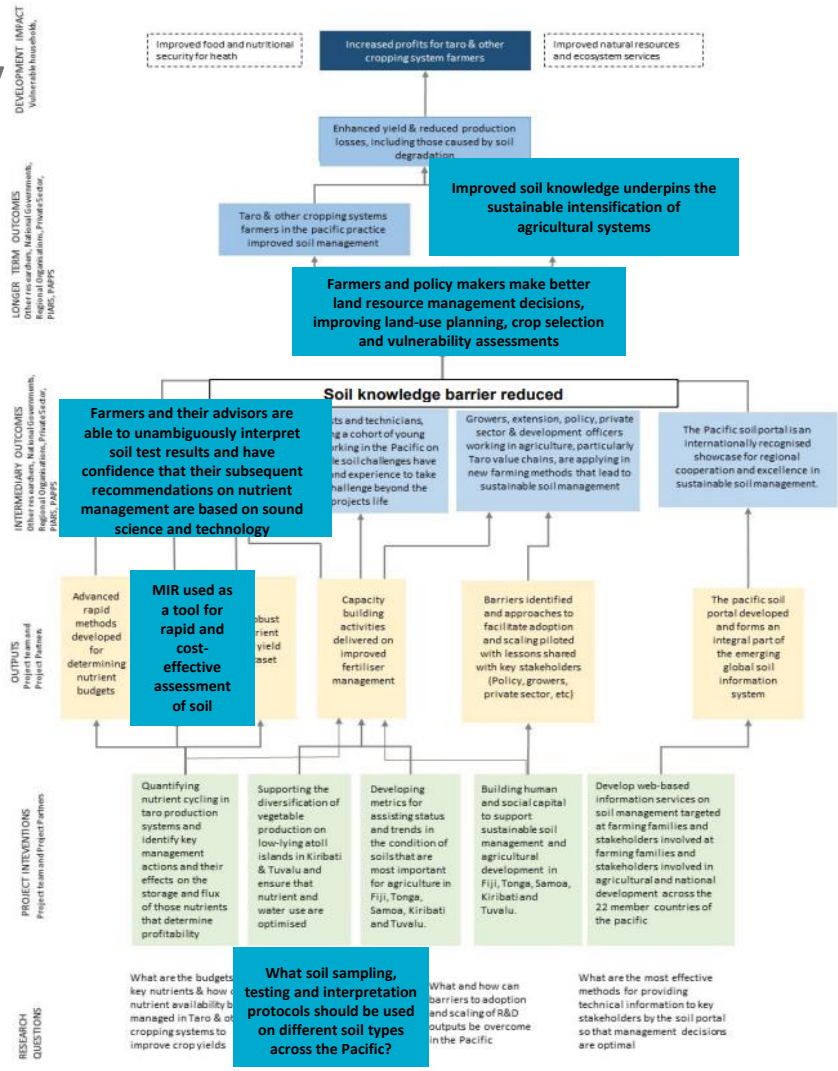
Response

Training of local staff in the use and operation of MIR technology to facilitate uptake of the technology as a valuable tool for rapid and cost-effective assessment of soil (impact pathway).

Impact pathway

Key assumptions

- MIR spectroscopy is a cost-effective approach to soil analysis
- MIR has been demonstrated to be used for the simultaneous estimation of soil physical, chemical and biological properties including clay and sand content, SOC, soil pH, CEC, exch Ca and Mg, TN, Fe, K, P, S
  (Stenberg et al., 2010; Soriano-Disla et al., 2014)
- IR spectroscopy has been used in Hawaiian and Columbian variable charge soils with success
  (Bonett et al., 2016; McDowell et al., 2012)
- Adoption can be achieved through standard protocol development and training
  (SMCN/2009/031, SMCN/2014/075)

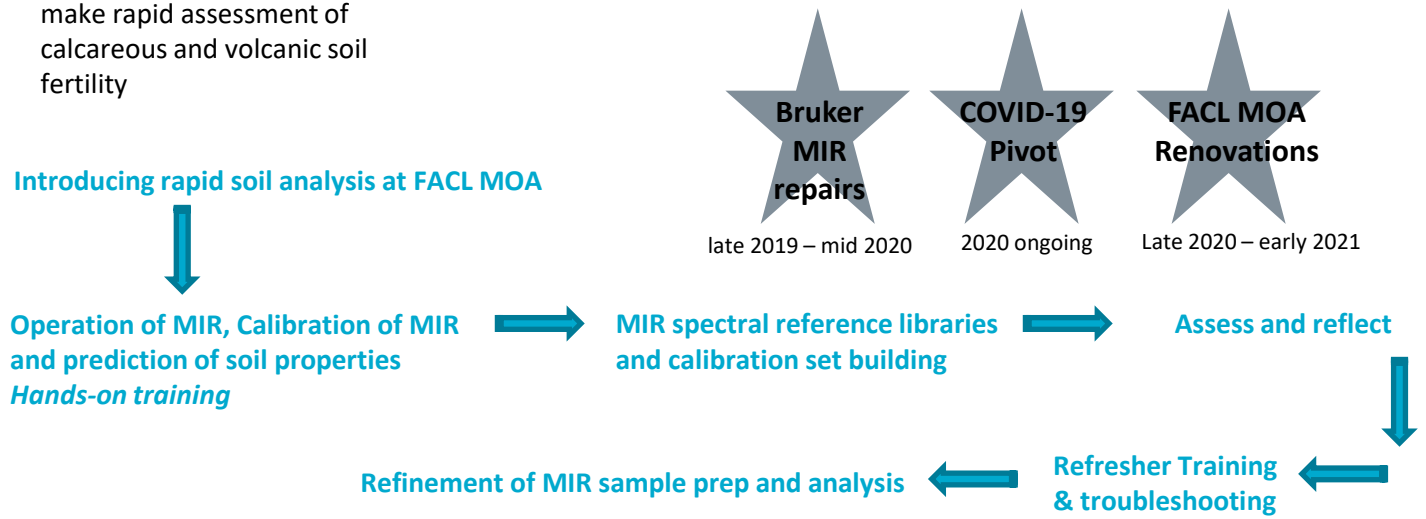


Approach & Challenges

Research question:

What soil sampling**, testing** and interpretation protocols should be used on different soil types in the Pacific?

ACTIVITY 3.12: Utilise MIR to make rapid assessment of calcareous and volcanic soil fertility



Output: Demonstrated potential of MIR to contribute together with traditional laboratory analysis methods to the development of a soil information system for the PICTs

What we achieved …

Key milestones delivered

Output:

MIR used as a tool for rapid and cost-effective assessment of soil

Capacity building activities delivered

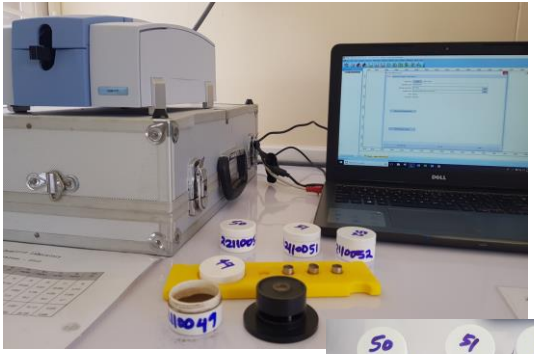
- Purchase of a Bruker Alpha-II-FT-IR (MIR) instrument and installation at FACL MOA
- 1 x 5-Day “MIR spectroscopy” training course for 11 MOA staff at Koronivia Research Station FACL MOA (5-11 May 2018) plus soil survey and sampling methodology and meta-data collection introduction
- FACL MOA team has independently set up MIR operations
- FACL MOA team has independently conducted MIR soil spectral inference and QC
- FACL MOA team has adopted MIR analysis in new National Soil Health Card program to build spectral libraries

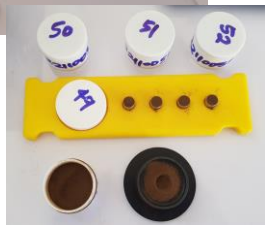
MIR spectroscopy – Laboratory protocols

- Rapid and cost-effective estimation of a range of soil properties simultaneously

- Sample preparation:
  - Air-dry, sieved < 2 mm
  - Air-dry (or oven dry at 40/60°C), and fine-ground (<0.5 mm)

- Soil specimen scanned in quadruplicates (~ 5 min per specimen)



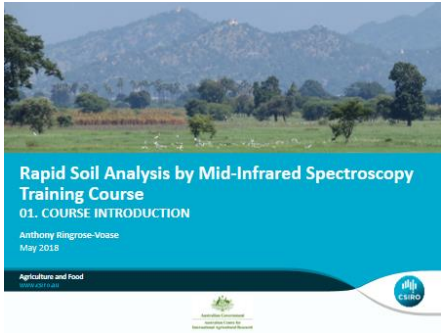


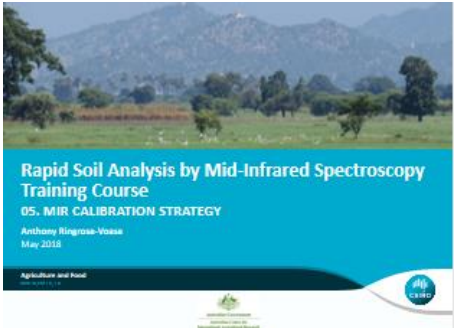
MIR spectroscopy – SoilSpecInference

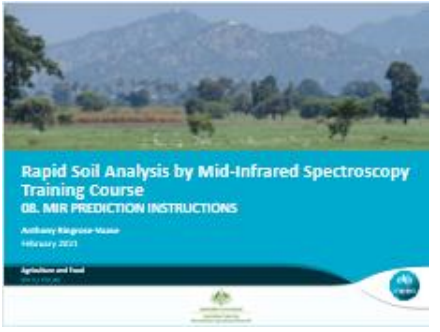
- Estimation of a range of soil properties of agronomic importance

Comprehensive step-by-step How To training materials:

- Calibration model generation for soil property prediction utilizing the Bruker Opus Software (built upon SMCN/2009/031)
- MIR calibration prediction (new)
- Custom-build Excel Macro for QC and averaging of quadruplicate soil property predictions





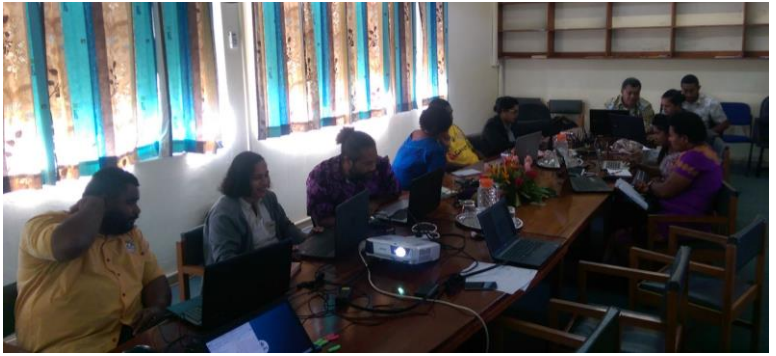


MIR spectroscopy – Training Photos

Fiji Agricultural Chemistry Laboratory MOA

Training participants in soil sample preparations, fine-ground (<0.5mm), using a mortar and pestle

Training participants in soil scanning protocols, quadruplicate MIR scanning



Training participants in soil spectral inference using the Bruker OPUS software

Morning Tea Time!

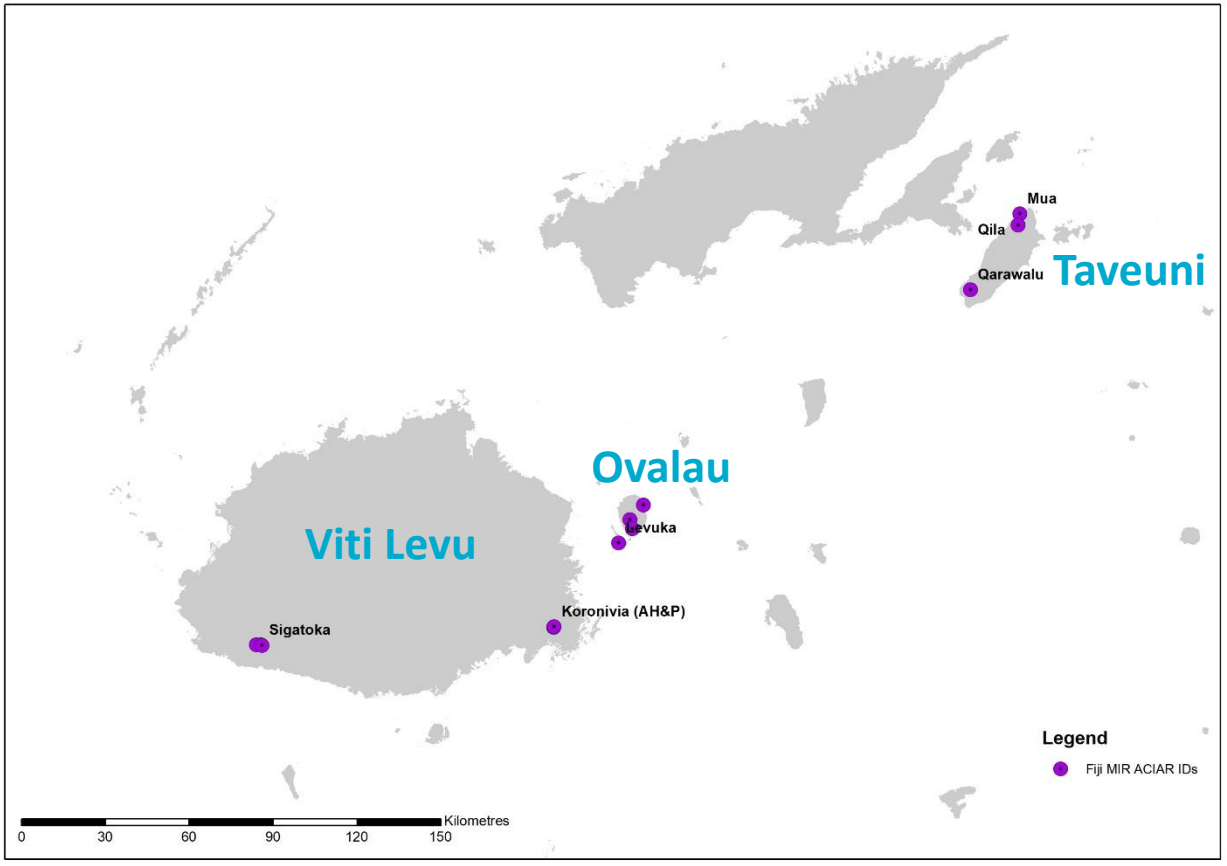
MIR Capacity building at FACL MOA

- The team at FACL MOA independently set up soil surveys in Ovalau (Levuka) and Viti Levu under the new Soil Health Card program
- Soil samples acquired to date have been/are analysed with MIR and traditional wet chemistry analysis methods, and will be used to build spectral library for Fijian soils of agronomic importance
- The team MIR scanned soil samples from the ACIAR field trials in Taveuni, and applied cal models developed from FACL soil archive samples.
- The team MIR scanned soil samples from the ACIAR field trials in Tonga

So what did we learn?

MIR spectroscopy – Fiji

Fiji islands sampling locations



MIR spectroscopy – Calibration results

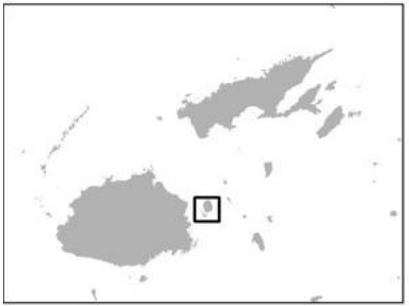
Fiji Agricultural Chemistry Laboratory MOA Taveuni Soil Archive samples (121)

Soil property	R^2	OK
EC	0.79	✓
Organic carbon	0.59	~
Exchangeable Mg	0.43	~
Extractable Mn	0.33	×
pH H_2O	0.30	×
Exchangeable Ca	0.29	×
Exchangeable K	0.18	×
TN	0.14	×
Extractable Fe	0.12	×
Extractable Zn	0.09	×
Extractable Cu	0.08	×

Soil property	R^2	OK
Available P (Olsen)	0.03	×
Exchangeable Na	0.02	×

MIR spectroscopy – Regional Calibration

Soil Health Card program – Fiji Ovalau island - Levuka sampling locations



MIR spectroscopy – Calibration results

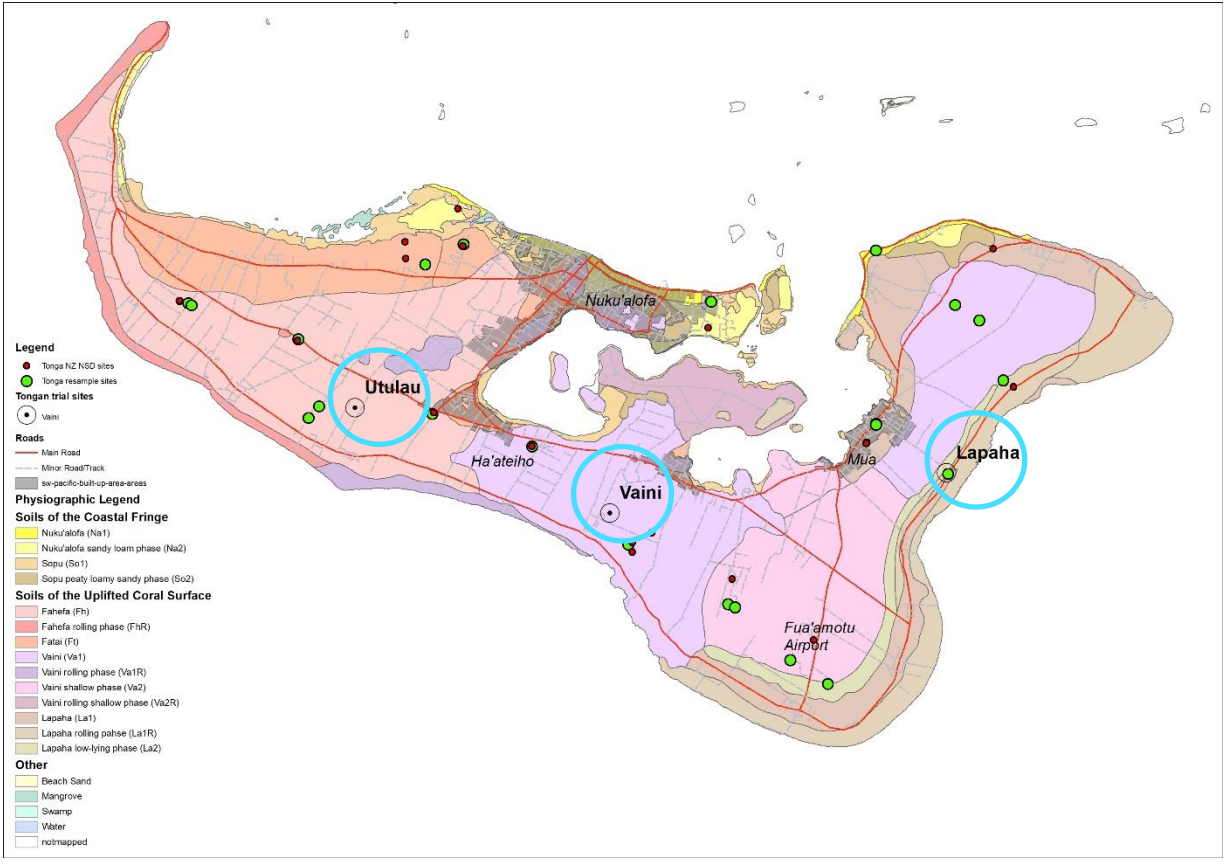
Soil Health Card program – Fiji Ovalau island – Levuka samples (142)

Soil property	R^2	OK
Exchangeable Ca	0.81	✓
Organic carbon	0.73	✓
pH H_2O	0.73	✓
TN	0.40	~
Extractable Mn	0.36	×
Exchangeable Mg	0.28	×
Exchangeable Na	0.16	×
Available P (Olsen)	0.08	×
EC	0.06	×
Extractable Fe	0.05	×
Exchangeable K	0.04	×

Soil property	R^2	OK
Extractable Cu	0.04	×
Extractable Zn	0.03	×

MIR spectroscopy – Local Calibration

ACIAR Tonga field trial sampling locations



MIR spectroscopy – Calibration results

ACIAR Tonga field trial samples (48)

Soil property	R^2	OK
Exchangeable K	0.96	✓
Extractable Cu	0.96	✓
Organic carbon	0.94	✓
Exchangeable Mg	0.93	✓
Extractable Fe	0.89	✓
Extractable Mn	0.89	✓
Extractable Zn	0.89	✓
Exchangeable Ca	0.77	✓
Exchangeable Na	0.73	✓
pH H_2O	0.73	✓
Available P (Olsen)	0.72	✓

Soil property	R^2	OK
TN	0.64	~
EC	0.56	~

- Results showed that MIR spectroscopy can be used successfully for allophanic soils for traditional soil fertility measurements
- Calibration results consistent with general rule that local cal generally give more accurate estimates – but limited to local calibration area
- Continue the building of soil spectral libraries of PICTs representative soil types -> improve predictive power of cal models

Rapid soil analysis – vis-NIR spectroscopy

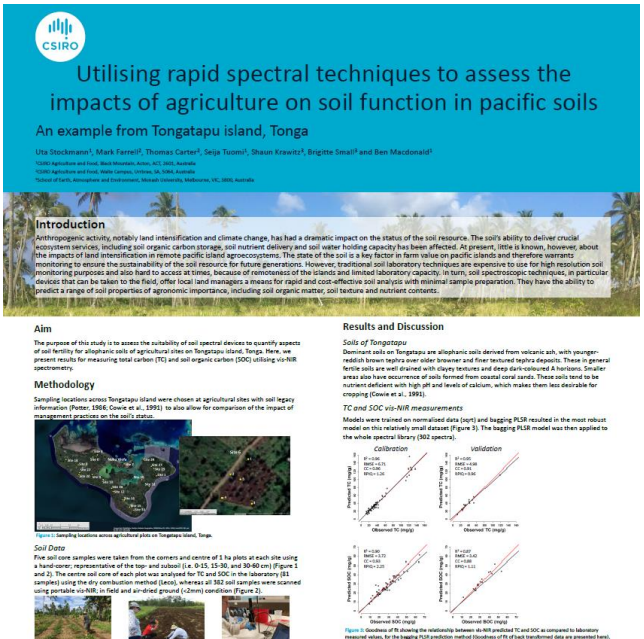
Tongatapu, Tonga

- Sampling locations across Tongatapu island chosen at agricultural sites with soil legacy information (Potter, 1986; Cowie et al., 1991)

- 81 samples to develop cal models
- Air-dried, sieved <2 mm

- Results showed that vis-NIR spectroscopy can be used successfully for allophanic soils for traditional soil fertility measurements

Soil property	R^2	OK
Total carbon	0.95	✓
Organic carbon	0.87	✓



Utilising rapid spectral techniques to assess the impacts of agriculture on soil function in pacific soils

An example from Tongatapu island, Tonga

Uta Stockmann[1], Mark Farrell[2], Thomas Carter[3], Seija Tuomi[3], Shaun Krawitz[3], Brigitte Small[3] and Ben Macdonald[3]

Introduction

Aim

Methodology

Soil Data

Prediction method

Results and Discussion

Soils of Tongatapu

TC and SOC vis-NIR measurements

Conclusions and Future work

Source: Stockmann, U. et al. Utilizing rapid spectral techniques to assess impacts of agriculture on soil function in pacific soils. In: 7th International Symposium on Soil Organic Matter in a stressed world; 6-11 October 2019; Adelaide, South Australia. som.org; 2019. 1 p.

Insights and lessons

- *"The purchase and installation of the new MIR instrument at FACL MOA by ACIAR provides Fiji and the PICTs enhanced capability to rapidly and economically analyse soil samples."*
- *"MIR is a most valuable tool to overcome challenges such as timely throughput of large numbers of soil samples, tight resources and budgets, acquiring large volumes of organic solvents for traditional wet chemistry analysis, which might not be locally available."*

Mr Ami Sharma, MOA

Insights and lessons cont.

- Building of robust spectral libraries for representative PICT soil types are important for rapid MIR analysis
- The new Fiji MOA Soil Health Card program, which aims to renew/update Fiji's soil attribute data and provides soil knowledge to land holders, is a timely opportunity to build MIR spectral libraries for Fijian soils
- Improvements are needed to connect the whole team to the internet to allow enhanced collaboration
- Improved use of digital laboratory note books and video/photo of procedures
- Soil database development needed

So what's next …MIR….NIR…pXRF

- Refining MIR spectral analysis protocols
- Developing protocols/steps for applying existing calibration models to new spectral data plus selection of sub-samples for wet chemistry analysis to improve existing calibration models
- Conduct soil survey of representative PICT soils to build spectral libraries and improve calibration model predictive power
- Collection of samples from 0-1m in the soil profile. Currently library biased to surface samples in most instances

Thank you

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