



Australian Centre for International Agricultural Research

Rapid and costeffective soil analysis utilizing IR technology

Pacific Soils: Final Review (Objective 3.2)

Uta Stockmann & Radheshni Singh November 2021



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



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).



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)





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



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







Capacity building activities delivered

MIR used as a tool for rapid and costeffective assessment of soil

Output:

- 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









- 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)









• 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





Fiji Agricultural Chemistry Laboratory MOA





Training participants in soil scanning protocols, quadruplicate MIR scanning

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





Morning Tea Time!

Training participants in soil spectral inference using the Bruker OPUS software

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









Fiji islands sampling locations





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

Soil property	R ²	ОК
EC	0.79	\checkmark
Organic carbon	0.59	~
Exchangeable Mg	0.43	~
Extractable Mn	0.33	×
рН H ₂ O	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	ОК
Available P (Olsen)	0.03	×
Exchangeable Na	0.02	×



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







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

Soil property	R ²	ОК
Exchangeable Ca	0.81	\checkmark
Organic carbon	0.73	\checkmark
pH H ₂ O	0.73	\checkmark
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	ОК
Extractable Cu	0.04	×
Extractable Zn	0.03	×



ACIAR Tonga field trial sampling locations





ACIAR Tonga field trial samples (48)

Soil property	R ²	ОК
Exchangeable K	0.96	\checkmark
Extractable Cu	0.96	\checkmark
Organic carbon	0.94	\checkmark
Exchangeable Mg	0.93	\checkmark
Extractable Fe	0.89	\checkmark
Extractable Mn	0.89	\checkmark
Extractable Zn	0.89	\checkmark
Exchangeable Ca	0.77	\checkmark
Exchangeable Na	0.73	\checkmark
pH H₂O	0.73	\checkmark
Available P (Olsen)	0.72	\checkmark

Soil property	R ²	ОК
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	ОК
Total carbon	0.95	\checkmark
Organic carbon	0.87	\checkmark

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

An example from Tongatapu island, Tonga



Aim

The purpose of this study is to assess the suitability of soil spectral devices to quantify aspects of soil fertility for allophanic soils of agricultural sites on Tongatapu island, Tonga. Here, we present results for measuring total carbon (TC) and soil organic carbon (SOC) utilising vis-NR spectrometry.

Methodology

Sampling locations across Tongatapu island were chosen at agricultural sites with soil legacy information (Potter, 1986; Cowie et al., 1991) to also allow for comparison of the impact of



Soil Data

Twe solitoner samples were taken from the corners and centre of 1 ha plots at each site using a hand corner, representative of the top- and subsol (i.e. 0-15, 15-30, and 30-80 cm) (Figure 1 and 2). The centre solit corn of each plot was analysed for 12 cm 30C in the laboratory (#1 samples) using the dry combustion method (Leco), whereas all 182 soll ramples were scanned



Control
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Prediction method

Spectral task adulting from a 'n which and grown(c).comm) joil samples were converted from interfactors to abundances, minuted, filtered (unity the Solitzlyck) fifter with a window tise of 10 mm and a polynomial algence of 2), baseline corrected using the standard normal unities technique and transmisel for data and unitational program. The prediction networks with the standard standard and the standard standard standard variabilities, RAS with internal and external validation (DOI), and baging RAS, which generates multiple RAS models and variable predictions (Paralations were used here).

> Uta Stodimann Agriculture and Food

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Results and Discussion

Soils of Tongatapu

Deministra soili on Tongatagu are allightainic soili derived from valcanic ash, with youngeredicib howan toppic over older howanc and frare totavale teptica depact. These is general ferritic soils are well drained with clayer tentures and deep dark-celoured A heritons. Smaller mares also have economics of soils formed from costal coral soits. Texas soils and economics and the soit of the nutriest deficient with high pland levels of calcium, which makes them less desirable for copping (Dowler et al., 1981).

TC and SOC vis-NIR measurements

Models were trained on normalised data (sort) and bagging PLSR resulted in the most robust model on this relatively small dataset (Figure 3). The bagging PLSR model was then applied to the whole spectral library (302 spectra).



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for reasons show one vorwing spectrometry can be used successfully for adoptions sole one reactional sole for titly measurements, and in upcoming work we will also examine its apability for other soll quality indices and soil properties. Furthermore, for this data-set, we vill also test algorithms to enable in-field measurement of soil attributes.

Conclusions and Future work

Our preliminary results indicate that the introduction of rapid spectroscopic techniques can play an important role for means of soil measurement of pacific island soils.

This study contributes to the building of a soil information infrastructure for pacific island soils, including soil spectral reference libraries, and data for basellene soil attribute assessments; which will contribute towards enabling informed land management decisions in the pacific liand region, and monitoring their status towards ensuring soil resilience.

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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.



- "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



- 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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Soil property - Fiji	R ²	ОК
EC	0.79	\checkmark
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Soil property - Tonga	R ²	ОК
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