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

An example from Tongatapu island, Tonga

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Introduction

Anthropogenic activity, notably land intensification and climate change, has had a dramatic impact on the status of the soil resource. The soil's ability to deliver crucial ecosystem services, including soil organic carbon storage, soil nutrient delivery and soil water holding capacity has been affected. At present, little is known, however, about the impacts of land intensification in remote pacific island agroecosystems. The state of the soil is a key factor in farm value on pacific islands and therefore warrants monitoring to ensure the sustainability of the soil resource for future generations. However, traditional soil laboratory techniques are expensive to use for high resolution soil monitoring purposes and also hard to access at times, because of remoteness of the islands and limited laboratory capacity. In turn, soil spectroscopic techniques, in particular devices that can be taken to the field, offer local land managers a means for rapid and cost-effective soil analysis with minimal sample preparation. They have the ability to predict a range of soil properties of agronomic importance, including soil organic matter, soil texture and nutrient contents.

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-NIR 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 management practices on the soil's status.

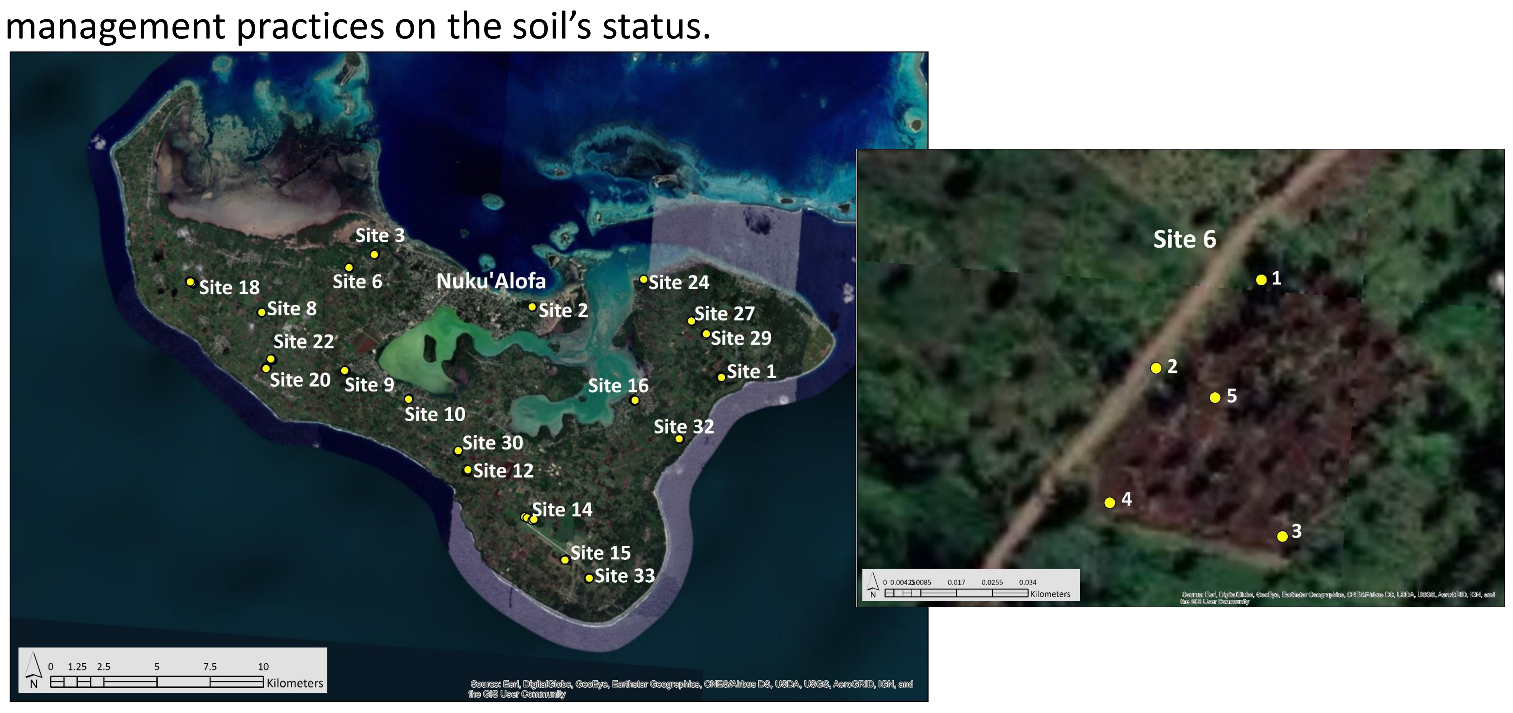

Figure 1: Sampling locations across agricultural plots on Tongatapu island, Tonga.

Soil Data

Five soil core samples were taken from the corners and centre of 1 ha plots at each site using a hand-corer; representative of the top- and subsoil (i.e. 0-15, 15-30, and 30-60 cm) (Figure 1 and 2). The centre soil core of each plot was analysed for TC and SOC in the laboratory (81 samples) using the dry combustion method (Leco), whereas all 382 soil samples were scanned using portable vis-NIR; in field and air-dried ground (<2mm) condition (Figure 2).

Figure 2: Soil sampling in the field, and spectral analysis using a Panalytical ASD LabSpec vis-NIR spectrometer.

Table 1: Statistics of measured TC and SOC content (mg/g) of the calibration dataset (Leco, dry combustion).

	n	Mean	Std. dev.	Median	Min	Max
Total carbon (mg/g)						
Calibration	61	43.19	33.10	32.39	12.51	136.52
Validation	16	39.43	24.15	31.7	11.66	118.61
Soil organic carbon (mg/g)						
Calibration	61	29.67	11.93	28.33	9.38	64.3
Validation	16	31.99	10.33	29.36	11.66	53.41

Prediction method

Spectral data obtained from air-dried and ground (<2mm) soil samples were converted from reflectance to absorbance, trimmed, filtered (using the Savitzky-Golay filter with a window size of 10 nm and a polynomial degree of 2), baseline corrected using the standard normal variate technique and resampled for data reduction purposes. Three prediction methods were tested for spectral calibration, partial least squares regression (PLSR) with no external validation, PLSR with internal and external validation (20%), and bagging PLSR, which generates multiple PLSR models and averages the predictions (50 realisations were used here).

Results and Discussion

Soils of Tongatapu

Dominant soils on Tongatapu are allophanic soils derived from volcanic ash, with younger-reddish brown tephra over older browner and finer textured tephra deposits. These in general fertile soils are well drained with clayey textures and deep dark-coloured A horizons. Smaller areas also have occurrence of soils formed from coastal coral sands. These soils tend to be nutrient deficient with high pH and levels of calcium, which makes them less desirable for cropping (Cowie et al., 1991).

TC and SOC vis-NIR measurements

Models were trained on normalised data (sqrt) 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).

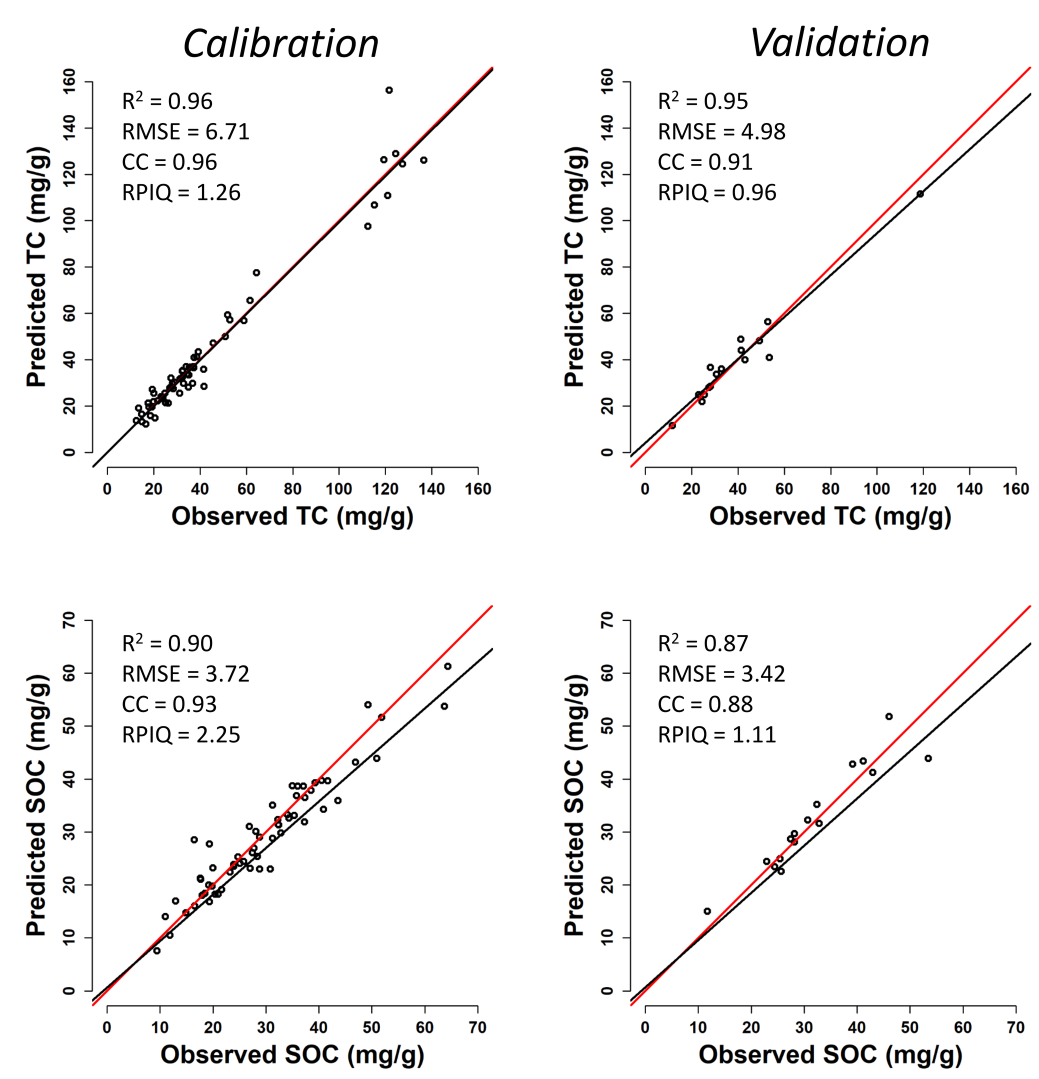

Figure 3: Goodness of fit showing the relationship between vis-NIR predicted TC and SOC as compared to laboratory measured values, for the bagging PLSR prediction method (Goodness of fit of back transformed data are presented here). R^2 – R squared coefficient of determination, RMSE – root mean square error (mg/g), CC – concordance correlation coefficient which measures the closeness to the 1:1 line, RPIQ – ratio of performance to inter-quartile distance.

Our results show that vis-NIR spectrometry can be used successfully for allophanic soils for traditional soil fertility measurements, and in upcoming work we will also examine its capability for other soil quality indices and soil properties. Furthermore, for this data-set, we will 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 baseline soil attribute assessments; which will contribute towards enabling informed land management decisions in the pacific island region, and monitoring their status towards ensuring soil resilience.

FOR FURTHER INFORMATION
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