Infrared Spectroscopy – moving from the laboratory to the field

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Abstract

Infrared spectroscopy has been shown to be a powerful technique in its ability to predict a range of soil and plant properties. With the advancement of this technology, hand held versions of both NIR and MIR spectrometers are now available which can be used in the field. Two examples of where IR technology could be important in supporting agronomic decisions is the prediction of Phosphorus Buffering Index (PBI) at a paddock level and the assessment of crop nitrogen status *in situ*. Recent studies have shown that both parameters were adequately predicted with the use of hand held instruments in the field. MIR predicted PBI values across a small section of a paddock with an accuracy of $R^2 = 0.90$. Portable NIR instruments were able to predict the N content of wheat at two growth stages with an accuracy of $R^2 = 0.94$. The performance of IR in predicting PBI and crop N content in the field was less than for processed samples in the laboratory but results are promising at an agronomic level.

Keywords

Phosphorus Buffering Index, Nitrogen content.

Introduction

Applications of infrared (IR) technology for the rapid and cheap prediction of soil and plant analytes are well known. Recently IR technology has advanced to include the production of portable hand held instruments that provide the opportunity for field use and therefore transferral of laboratory predictions of soil and plant analytes at a field scale could have significant benefits to making agronomic decisions. In this paper we report on the ability of IR technology to measure, *in situ*, two important soil and plant parameters in the field; soil Phosphorus Buffering Index (PBI) and crop N content.

Phosphorus Buffering Index

PBI is an important soil characteristic describing P mobility which drives P fertility, P fertiliser reactions and is crucial in defining critical levels of Colwell P (Moody 2007). The main soil parameters that influence PBI values and generate higher fixation of added P inputs are calcium carbonate, and iron/aluminium oxides. These soil characteristics can change rapidly across soil landscapes which influences the resulting soil PBI. Therefore a technique which enables rapid and cheap analysis of PBI across a paddock would potentially add great value to variable rate technology by focusing P inputs where P fertiliser efficiencies are low.

Mid-Infrared technology (MIR) has been shown to accurately determine the concentrations or proportions of major soil properties that influence the soil's ability to retain P. MIR-predicted P buffering values have been shown to be strongly related to PBI measurements across a large range of PBI values (Forrester et al. 2014). Handheld MIR potentially allows for the generation of paddock PBI maps but the influence of field conditions on MIR-PBI predictions has yet to be tested.

Determination of crop nitrogen status

In-season nitrogen applications can be a highly efficient method of meeting crop N requirements if seasonal conditions are favourable. Decisions around the timing of N applications can be made based on numerous factors including follow up rain, current crop N content and predicted yield potentials. In some cases, these assessments need to be made quickly and therefore the time delay involved with sending crop samples off to a laboratory for N analysis might be costly. Rapid analysis of current crop N status *in situ* could potentially alleviate these pressures.

IR technology has been shown to accurately predict total N contents in a range of crop types when the material is dried and processed (Batten 1998, Mason et al pers comm, Figure 1). Both the near and mid IR range was found to be suitable predictors. NIR might be more applicable for field assessment due to the wider beam widths and the fact that portable NIR instruments allow assessment of crop N status *in situ*. If sufficiently accurate, portable in-field NIR would be an important tool in making on-the-go N input decisions.

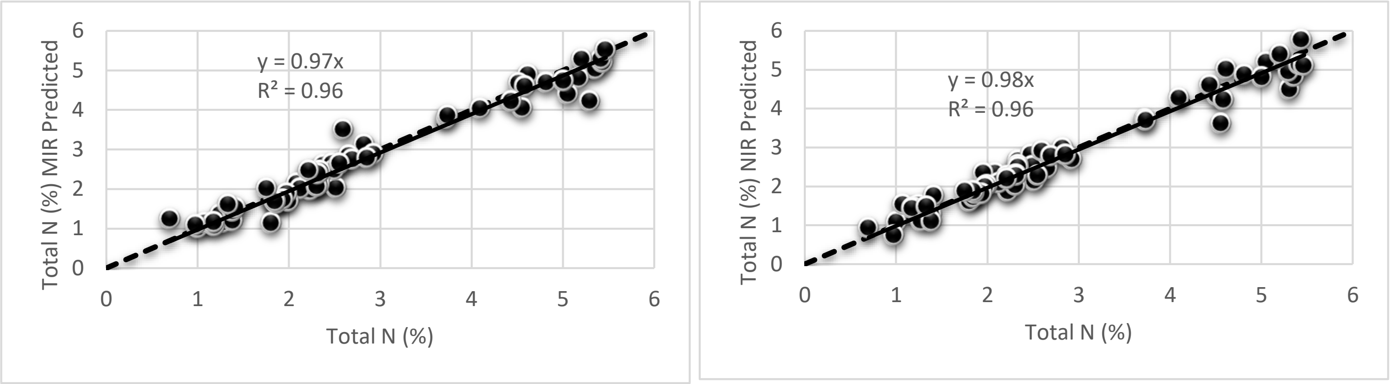

Figure 1. Relationship between the prediction of total N contents of various crop types based on a large calibration dataset and the measured total N contents for MIR (left) and NIR instruments (right).

Methods

Phosphorus Buffering Index

An assessment of the ability of MIR technology to be able to map PBI across a paddock was performed at a focus paddock near Karoonda, South Australia which had a typical dune swale system and varying PBI values (Figure 2). Samples were taken in a grid format (120 m x 60 m) after significant rainfall events and therefore the effect of soil wetness on the MIR determination of PBI could be evaluated (wet soil is particularly problematic for MIR analysis of soils). The soil sampling methodology involved taking 2 cores to a depth of 0-10 cm in a concentrated area. The soil cores were directly scanned by a hand held ExoScan MIR instrument to obtain spectra from intact field cores. Cores were also combined, mixed and rescanned with the MIR (Field – homogenised). The composite soil sample was then bagged and brought back to the laboratory for further analysis. On reaching the laboratory, the sample was dried and sieved (< 2 mm) and fine ground (< 150 µm). MIR spectra were again obtained on the laboratory-processed samples in addition to the chemical PBI determination in the laboratory. Partial least square regression (PLSR) models were derived from the MIR spectra and reference data.

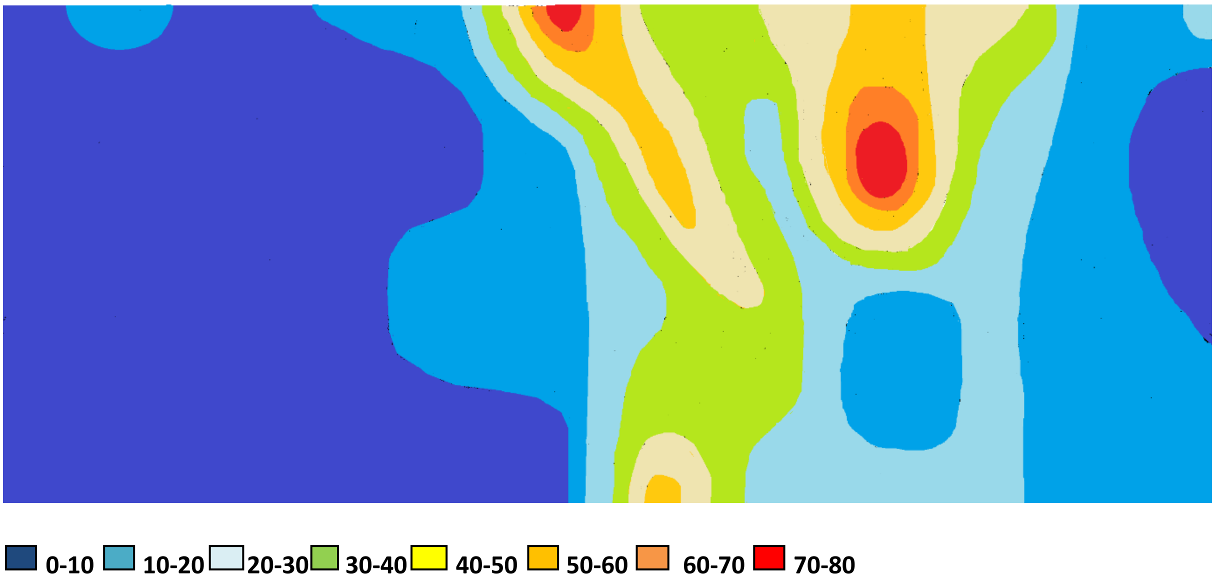

Figure 2. PBI values (measured – laboratory) across a section in a paddock (120 x 60m) at Karoonda.

Determination of crop N status

Two small plot N response trials assessing effects of two different times of sowing on utilisation of N inputs on a rage of wheat varieties were used to determine the capabilities of NIR to predict crop N contents in field environments. These plot trials were located at Mintaro, in the Mid-North region of S.A. Plots were scanned using a NIR instrument (FieldSpec Handheld Spectroradiometer) at a height of approximately 0.5 metres similar to the method that Greenseekers™ use to scan vegetative growth. Plots were scanned at early and late reproductive growth stages. Samples of crop from each plot were taken and brought back to the laboratory where they were dried and ground. Processed samples were then scanned by portable NIR instruments. in addition to a benchtop MIR/NIR (Perkin-Elmer Frontier FTIR) instrument followed by traditional laboratory analysis to determine total N contents. PLSR) models were derived from the NIR/MIR spectra and reference data.

Results

Phosphorus Buffering Index

Using a site-specific calibration model developed from a subset of the Karoonda samples, PBI values were predicted for all samples with high accuracy (Figure 3 left). The subset was selected by identifying spectra describing the maximum spectral, and thus compositional, variability of the entire set. There was a strong relationship between PBI and soil moisture content at this site (R^2= 0.90). Thus, an additional model was built from a combination of MIR spectral information plus soil moisture as the independent input variables, obtaining an even better and very accurate model for predicting PBI (R^2 = 0.98, Figure 3 right). A previously developed PBI PLSR calibration model from a large set of soils across Australia (Forrester et al. 2013) was also successful in predicting PBI at the Karoonda site (data not shown).

These results confirmed the excellent potential of the hand-held MIR spectrometer for the prediction of PBI values in soils from a specific site, using both a site-specific and a global model. The use of one or the other calibration is likely to be dependent on the required accuracy and in field variability. We also showed that by careful sample subset selection, based on IR spectra of a few critical samples, we can model an entire site very accurately.

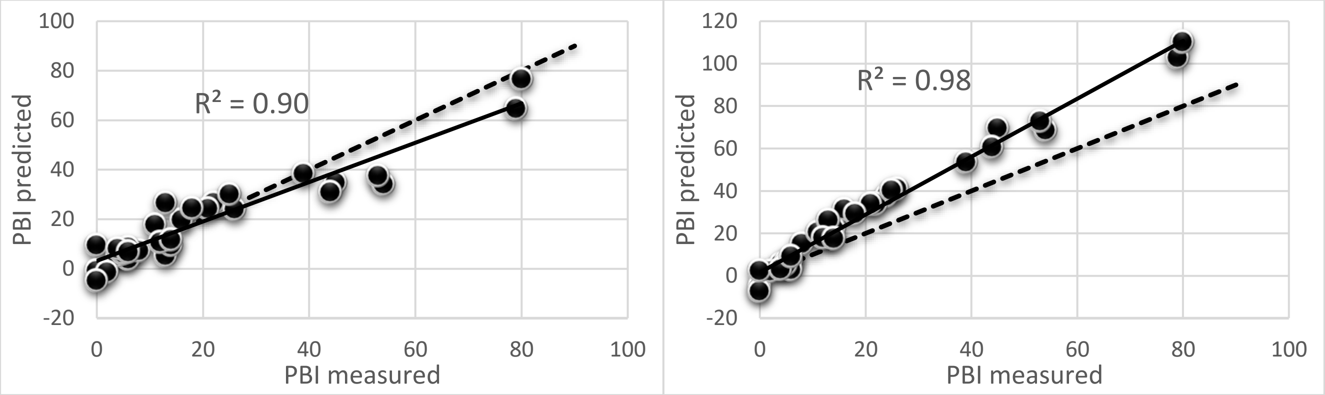

Figure 3. Site-specific validation of PBI values from Exoscan spectra of field-moist Karoonda soils versus laboratory determined PBI. PLSR calibration models derived from only PBI data and MIR spectra (left), and PBI data and MIR spectra plus soil moisture contents (right).

Determination of crop N status

Initial cross validation models for in-field assessment of wheat N content, using portable NIR, are promising (Figure 4). Data across all sowing times and growth stages was combined and high coefficients of determination (R^2 = 0.94) were obtained between measured and predicted crop total N contents. It appears that scans on the earlier vegetative stage (GS31) are more accurate compared to the flowering growth stage, but interestingly, the two different growth stages appear to sit in the same regression line.

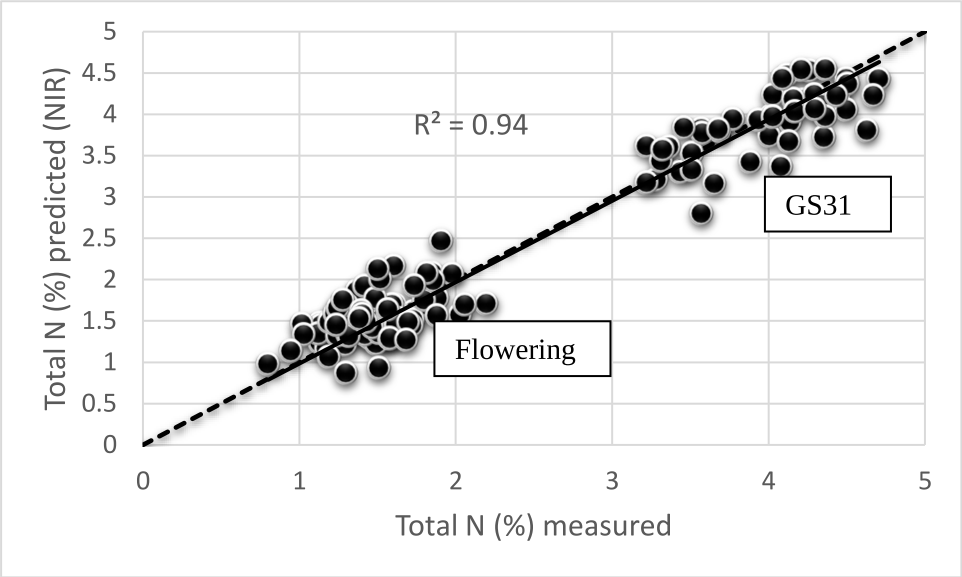

Figure 4. Cross validation of measured total N crop values with predicted crop N contents using portable NIR in field spectrometer.

Conclusion

Advances in IR technology have made available portable instruments with soil prediction performances similar to IR instruments previously restricted to the laboratory. For some important agronomic parameters, the IR technology is a promising technique. Validation of in-field instrument performance with traditional laboratory analysis is, however, still vital in order to maintain accuracy. Initial results suggest that portable IR technology allow for rapid and cheap assessment of PBI and crop N status, two important considerations for making fertiliser input decisions. With any in-field instrument. baseline checks need to be in place in order to maintain result integrity. These include quality control measures that would see samples run in duplicate, using soil samples with known results if applicable and sending a certain proportion of samples to the laboratory for validation (e.g. 10%).

References

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