SHORT COMMUNICATION

THE POTENTIAL ROLE OF NEAR INFRA RED REFLECTANCE (NIR) MONITORING IN PRECISION AGRICULTURE (PAG)

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Abstract

The adoption of precision agriculture technologies is probably one of the greatest challenges and opportunities of the 21st century to expand the horizons of soil and plant analysis by matching the spatial variability of soil properties and crop demand with a variable input of agro-resources in the field. The high cost of soil sampling and chemical and physical analysis by conventional laboratories has restricted the full implementation of this technique at field level. Near Infra Red (NIR) analysis could be a cost-effective solution, but a whole paradigm shift in philosophy is needed to move away from the traditional approach in soil testing of taking a ‘perceived’ representative sample in which all the spatial variation is lost, to using a combination of grid soil sampling at a sample intensity of 4 to 10 cores per ha, in which the sub samples are analysed separately using rapid but less accurate methods such as NIR.

Agricultural industries worldwide are showing increasing interest in the potential applications of near infrared (NIR) analysis in the fields of soil fertility, cane nutrition, cane quality testing and screening for resistance to certain pests and diseases. Recent investigations in the sugar and wheat industries have demonstrated the feasibility of using NIR scanning techniques for mapping spatial variability of important soil properties on a field scale. Soil properties that have been calibrated include gravimetric soil water, clay, buffer capacity, pH, electrical conductivity, titratable acidity, organic matter, mineralisable nitrogen, potential ammonia volatilisation from urea, potential nitrification rate, and urease activity. Mapping spatial variability in this way will enable better utilization of resources such as the application of fertilisers.

Keywords: near infrared, precision agriculture, soil mapping, soil testing, fertilisers

Introduction

Precision Agriculture (PAG) or Site Specific Management practices have grown in leaps and bounds in the USA and other countries and has paved the way for efficient use of resource inputs such as herbicides and fertilisers while maximising crop production. The concept of Precision Farming, also known as ‘soil or site specific management’, ‘farming by soil’and ‘farming by the foot’, is not new, and interest in the potential benefits of PAG gathered momentum in the late eighties. Advances in computers and greater precision in remote sensing capabilities have largely spawned the emerging technology of PAG. In the USA, combines in the wheat industry are highly computerised and continuously measure grain yield during harvest, enabling the compilation of yield variability maps.

Despite these advances, the high cost of soil sampling and analysis in conventional laboratories has restricted the full implementation of PAG and the development of soil spatial variability maps at the field level. NIR could be a cost-effective solution but a whole change of philosophy will be needed in soil testing to move away from the traditional approach of taking a ‘perceived’ representative sample in which all the spatial variation is lost and where highly accurate chemical methods are used to using a combination of grid soil sampling based on a sample intensity of 4 to 10 cores per ha, in which the sub samples are analysed separately using rapid but less accurate methods such as NIR. Mapping spatial variability in this way will enable better utilization of resources such as the application of fertilisers.

Until recently in the sugar industry, NIR detectors have been calibrated for manual scanning of soil and leaf samples in the laboratory (Meyer, 1983; Meyer, 1989; Meyer *et al*, 1995) and for monitoring cane quality (Meyer and Wood, 1988; Berding *et al*, 1989; Clarke *et al*, 1995; Schaffler and Meyer, 1996). Early NIR investigations in the sugar industry have confirmed that nitrogen use efficiency of sugarcane could be improved by matching the crops N requirement to NIR derived soil N mineralising potential classes and the N status of the plant (Meyer *et al*, 1986).

Methods and Results

Recent investigations at SASRI, based on intensive topsoil grid sampling of a small 0.342 ha field, demonstrated the feasibility of using an in-field portable NIR spectrohpotometer with autosampler for sampling and on-line analysis of soils (Schumann and Meyer, 1999). Good calibrations were obtained with ISI software, using modified partial least squares regression on a smaller sample subset (for example, clay % R^2=0.97, n=72). Other soil properties, including gravimetric soil water, buffer capacity, pH, electrical conductivity, titratable acidity, organic matter, mineralisable nitrogen, potential ammonia volatilisation from urea, potential nitrification rate and urease activity, could be measured despite the use of field-moist unprepared soils in the NIR instrument. Validation of the clay equation (n=60) demonstrated that an acceptable standard error of 2.1% clay was possible with this technique. Predicted NIR results (n=575) were used to prepare a GIS map showing up to 15 clay boundaries.

A more recent grid sampling exercise was conducted with soils in the South Western Cape to determine spatial variability over different fields (van Vuuren *et al*, 2005). 481 samples were taken from a one hectare grid over several fields (Samples were air dried and sieved through a 2 mm sieve. Standard soil analysis methods (Anon, 1990) were used for the analysis of the all the samples. All the samples were scanned on a Perten 7200 Dual Array NIR Spectrophotometer. The calibration set comprised 12% of the 481 samples and the constituents that were measured included pH (KCl) (R^2=0.86) Bray 1. Phosphorus (R^2=0.76) plant available Ca, Mg, K, Na (R^2=0.71, 0.82, 0.71, 0.64 respectively) (n=481), and organic carbon (R^2=0.93) (n=182). The calibration equations were used to predict the constituent values of the remaining samples. Comparison of the chemical analyzed and NIR predicted values are shown in Table 1. Maps were drawn showing the predicted (12% analysed values used in the calibration) versus all samples analysed.

Conclusions

The cost of production factors such as fertiliser and herbicide inputs is likely to escalate in the future as the oil price continues to rise, and there will be increasing interest by growers in the use of PAG to optimise resources. Factors such as parent material, topography, vegetation material and climate lead to great variation in soil type in cane fields, which implies that in future more samples per hectare need to be taken to get a better indication of the relative variability over a field. It is envisaged that grid soil sample based NIR tests will play an important role in characterising spatial variability of soil fertility across a field. This will enable Global Positioning System (GPS) controlled fertiliser applicators to vary the amount of fertiliser applied to a field according to soil test results. In time, portable NIR scanning systems which are already available from a number of companies, will be the key to successful implementation of PAG, as the low frequency of sample chemical analysis, which is needed to calibrate and validate the NIR for a particular site, will greatly reduce the costs of analysis.

Table 1. Comparison of NIR calibration and validation performance of a range of soil constituents.

Constituent	No. of samples	Range	Mean±SD	Calibration		Validation			
				R^2	SEC	r^2	SEP	RPD	RER
pH(KCl)	481	4.48 - 7.77	5.63±0.51	0.86	0.10	0.76	0.25	2.04	13.2
Bray1 mg/kg	481	6 - 498	41±44	0.76	6	0.65	19	2.32	25.9
NH4OAc-Ca mg/kg	481	471 - 5981	1327±625	0.71	193	0.69	196	3.19	28.1
NH4OAc-Mg mg/kg	481	80 - 704	247±87	0.82	17	0.85	33	2.63	18.9
NH4OAc-K mg/kg	481	20 - 1878	300± 212	0.71	67	0.77	80	2.65	23.2
NH4OAc-Na mg/kg	481	80 - 704	80±58	0.64	16	0.60	20	2.90	7.1
Carbon %	182	0.48 - 3.44	1.85±0.7	0.93	0.12	0.91	0.29	3.50	14.8

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