Effect of sampling strategy for in-field pasture quality measurement

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Introduction

The aim of this study was to assess the importance of spectral collection methods when using a field near infrared (NIR) device for direct measurements of pasture quality. Our prior work with a mobile NIR-based measurement device has had mixed results. Further investigation of strategies to improve calibration performance is required. Specifically, the effects of area scanned per sample and several processing methods were explored and have resulted in a marked increase in performance capability suggesting that results from previous work can be improved upon.

Real-time (or near real-time) information on pasture quality has the potential to provide substantial benefit to farmers through improved pasture utilisation and animal energy intake. Previous work[1] has focused on the acquisition of vast datasets and investigated the effect of sampling height, sampling speed and water on pasture. The work has yielded results with promise, but not to a degree enabling accurate measurement and hence application in their current form.

Pasture quality attributes including fibre and protein content, and metabolisable energy have been used for the assessment of improvement. Specifically these include Acid Detergent Fibre (ADF), Neutral Detergent Fibre (NDF), Organic Matter Digestibility (OMD), Metabolisable Energy (ME), Dry Matter % (DM) and Crude Protein (CP).

Materials and methods

The dataset consists of 100 separate measurement sites (0.25 m^2 quadrats) taken from ten paddocks in the Waikato region of New Zealand. The sample area allows an adequate quantity of material to be collected for low quality pasture to allow satisfactory testing.[1] Paddocks assessed were typically used for dairy grazing and sample sites covered a range of pasture quality. Quadrats were scanned at five sites within each quadrat, near each corner and in the centre (Figure 1), to increase coverage of the sampled area to 0.039 m^2 (16%), resulting in 500 spectra overall.

Following this, quadrats were cut to estimated grazing height, sorted, dried, weighed and sent to laboratories for reference testing using NIR spectroscopy measurements from commercial calibrations.

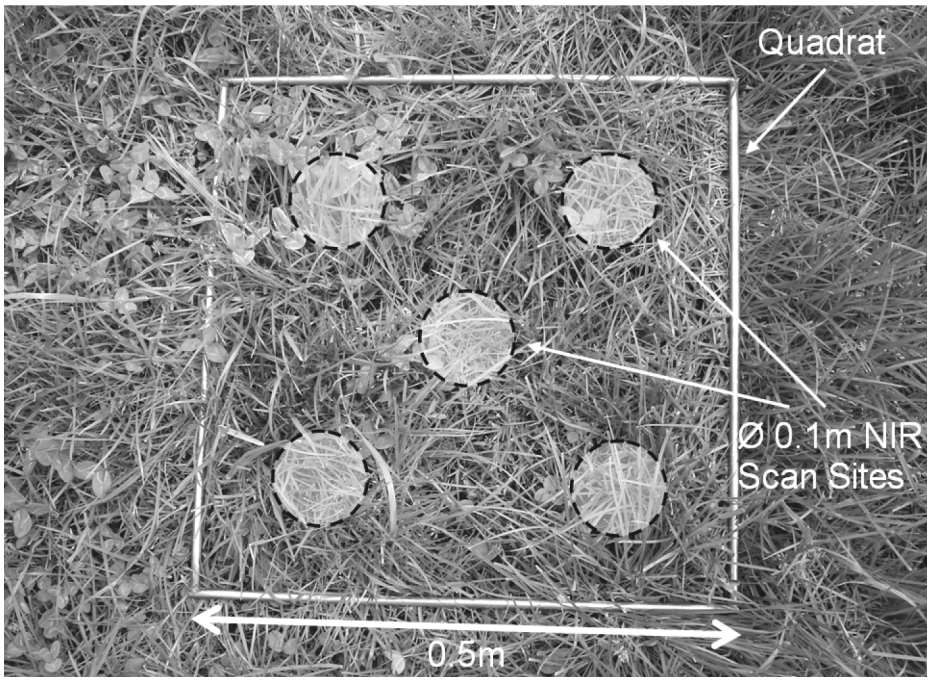

Figure 1. Quadrat sample area and NIR scan coverage.

A diode array spectrophotometer constructed by KES Analysis,[2] with a spectral range of 400–1700 nm, a selected wavelength interval of 5 nm and 0.1 m diameter sensing zone was adapted for field use (Figure 2) such that mobile scans could be taken.

Non-moving scans were taken in this study, where each scan was the average of 30 sub spectra. Each of the five sites per quadrat were scanned in three replicates and averaged, resulting in an available dataset of 500 scan sites and spectra. Prior to and following data acquisition in each paddock, the Calibration Tile (CT) was scanned.

Data analysis was performed using Matlab R2006b[3] and the PLS Toolbox.[4] Spectra from unique quadrats were split into calibration and validation sets in the ratio 2:1, and spectra from the CT were used to calculate Reflectance (REFL) and Absorbance (ABS). PLS regression models were chosen by leave-one-out cross validation using the calibration set for both REFL and ABS datasets. The best model for predicting each attribute was then determined by the least *RMSEC* before being applied to the validation set.

The four processing methods assessed were: 1) Use only the central site per quadrat to build calibration and validate against (100 spectra); 2) Use the average spectrum of the five scan sites to build calibration and validate against (100 spectra); 3) Use all spectra for each quadrat to calibrate and validate against (500 spectra); and 4) Use all spectra to build calibration and validate with the average of 5 predictions per site per quadrat (500 spectra). Method 1 has 3% sample area coverage, while the latter three have 16%.

Figure 2. TOBI measurement system.

Results and discussion

The goal of testing different sampling strategies is to improve the accuracy of the calibration, but also given the set sample area, it also addresses how the validation should be performed to best represent the quadrat.

Table 1. Validation metrics for four sample methods.

Attribute		Parameter range	Method 1		Method 2		Method 3		Method 4	
			R^2	*RMSEP*	R^2	*RMSEP*	R^2	*RMSEP*	R^2	*RMSEP*
1	Acid detergent fibre	8.51–13.17	38	2.48	72	1.68	60	2.03	76	1.81
2	Neutral detergent fibre	55.84–92.23	12	5.68	62	3.67	60	3.78	75	3.35
3	Organic matter digestibility	19.36–34.96	45	5.20	77	3.40	67	4.06	77	3.68
4	Metabolisable energy	28.29–58.82	52	0.58	71	0.45	70	0.46	79	0.42
5	Dry matter (%)	14.80–31.22	84	2.24	89	2.10	82	2.97	90	2.83
6	Crude protein	8.09–28.41	32	2.96	52	2.46	57	2.30	70	2.08

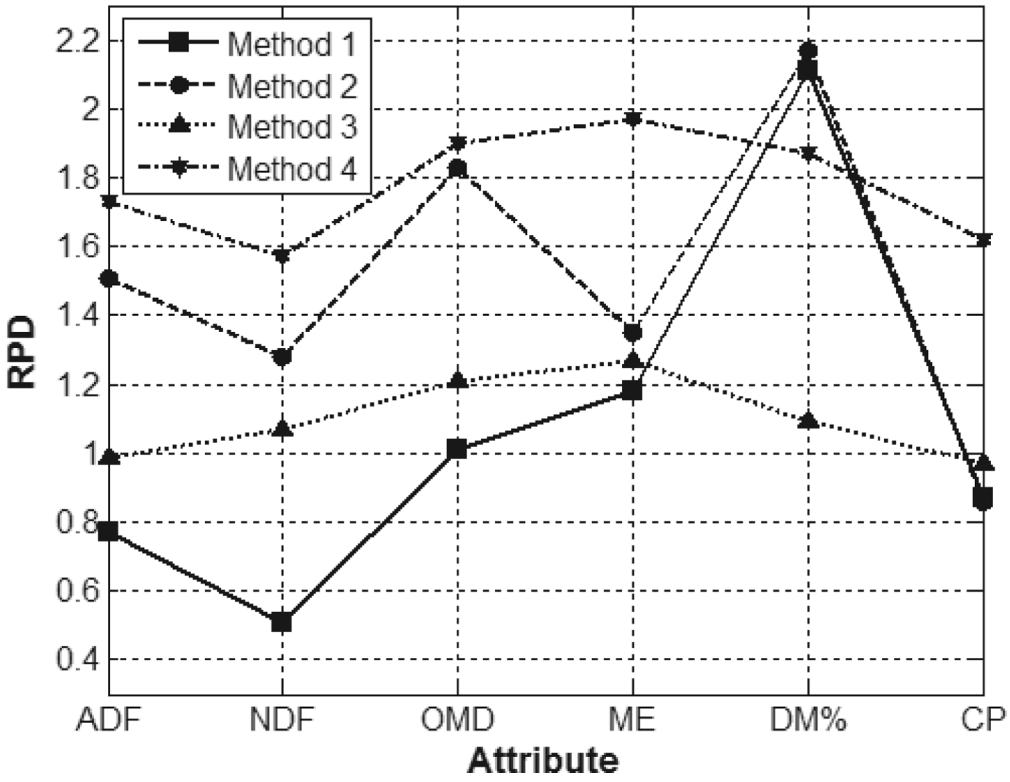

Figure 3. Processing method comparison by *RPD*.

The performance statistics in Table 1 show that the original sampling strategy (method 1) using one site per quadrat had the worst performance for all quality attributes except DM%.

This indicates that increasing the proportion of sample area scanned improves the performance of the calibration. However similar results to method 1 for methods 2 and 3 for attributes ME and CP show that even with greater sample coverage improved performance is not guaranteed. The error in method 3 will be greater than other methods as it is the sum of the errors at 5 sites, whereas the errors of other methods are averaged over the quadrat. As methods 3 and 4 are the same except for the final averaging of predictions, the marked difference in performance can therefore be thought of as an indicator of the attribute variation within a quadrat. However, this study has not assessed the performance at different levels of scan coverage or noted what degree of coverage is necessary to best capture the pasture variation given a fixed sample area.

The main difference between methods 2 and 4 is due to averaging, either of the spectra in the former case or of the predictions in the latter case. With a Ratio of Prediction to Error (*RPD*[5]) greater than 1.5 for all attributes (see Figure 3), method 4 performs better than method 2, except for DM%, indicating that spectra should not be averaged over the quadrat.

Similar results between methods indicate that this approach is more important for some attributes than for others.

Conclusion

Assessment of an NIR measurement system for pasture measurement requires adequate coverage of the sample area to generate reliable and accurate calibrations. The outcome of this study suggests that a better match between the reference and NIR sample area through either greater scan number per quadrat, or conversely reducing the sample area, would result in improvement to predictive performance. This should be combined with the processing strategy whereby multiple spectra for each quadrat are applied individually to build the calibration, and validated by averaging the set of predictions to better represent the quality over a quadrat. However, a compromise between the logistics of acquiring a more comprehensive dataset must be weighed with the level of performance required.

Through the aforementioned improvements to sampling strategy it is expected that the value of using NIR for the measurement of pasture quality may be better assessed, and will result in better performance than previously seen.

References

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