PASTURE QUALITY MEASUREMENT TOOLS FOR DECISION MAKING

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Abstract

Pasture quality is an important component in grazing and livestock management and a key driver of animal performance. Accurate, real-time information on pasture quality can help farm managers in decision making. This study investigated the potential applicability of optical sensors to estimate pasture quality parameters in the field, these have been trialled as part of the P21 Feed Programme, contract No. C10X0604. This paper summarises the spectral approaches which have been taken to investigate the potential of:

1) The Multispectral approach, where sensing devices (Crop Circle™ and CROPSCAN™) have a limited number of spectral bands, around the VIS and NIR parts of the spectrum with broad spectral resolution, these can be used to estimate pasture quality parameters such as crude protein.
2) A Hyperspectral approach provides fine resolution, using reflectance data spanning from 350 nm to 2500nm, to derive estimates of crude protein, acid detergent fibre, neutral detergent fibre, metabolisable energy, lignin and organic matter digestibility.

To extract spectral information and to correlate with reference values, various statistical tools (univariate and multivariate techniques) were used. All in-field measurements were supported by an extensive programme of laboratory NIR and wet chemistry measurements for calibration and validation. Initial results suggest that pasture quality can be accurately estimated using optical sensors and associated statistical methods, providing a useful management tool for farmers.

Introduction:

In New Zealand, grazed pastures are the main source (85% or more of the total feed) for livestock feed, hence it is considered economically significant. In pasture management, measurements of pasture quantity are an essential operation for efficient feed management and to improve animal performance (Holmes, *et al.*, 2007). To this date, pasture mangers used a wide range of mainly pedestrian quantity measurement devices in decision making. More recently the C-Dax Pasture Meter® has been used; this is attached to an ATV and provides rapid measurement of pasture as well as integrating with farm management software to provide a more efficient measurement system. Although a significant step forward, quantity based decision may still have their limitations as pasture quality is variable through seasonal and management effects, these influence animal performance. Consequently, quality based decision making approaches are being developed; thereby animal performance could be improved by optimising the pasture component of the diet. These would be used in conjunction with pasture quantity methods to establish the total nutrient availability in a pasture sward. Pasture quality can be described as how well it supplies nutrients to meet the requirements of a dairy cow. The composition of pasture quality can be described as different things by different people as crude protein, fibre, energy and sugars. In contrast, this study included a wide range of components: crude protein (CP), acid detergent fibre (ADF), neutral detergent fibre (NDF), ASH, lignin, lipid, dietary anion-cation difference (DCAD), organic matter digestibility (OMD) and metabolisable energy (ME) as pasture quality. Traditionally, pasture quality can be estimated by wet chemistry but this procedure involves cutting, drying, grinding, chemical analysis, a time-consuming and expensive process. Recently, near infrared spectroscopy (NIR) was developed from research and is now widely used in various laboratories for analysing feed biochemistry. This approach still requires the cutting, drying, grinding and preparation of the samples.

Alternatively, remote sensing technologies have proved to be useful and are being investigated for monitoring the biophysical and biochemical variation in green vegetation (Pullanagari, *et al.*, 2011). In this research, the potential of remote sensing devices for quantifying the pasture quality parameters was investigated.

The tools used in this study to investigate the prediction ability of pasture quality components are multispectral sensors (CROPSCAN™ and Crop Circle™) and hyperspectral sensor (ASD Field Spec® Pro).

Materials and methods:

The experiments were conducted under commercial dairy farm over various locations across New Zealand. The selected locations are Palmerston North, Hamilton and Canterbury which reflects a wide range of agro-climatic conditions results in a wide variation in pasture quality component values.

The Crop Circle™ has three channels, two visible (670 nm, 730 nm), and one at the near infrared, (760 nm), region, the width of the channels around 20 nm. In addition, this sensor has its own light source for energy hence called as active sensor. The spectral range of CROPSCAN™ 460 to 1680 nm with 10-16 nm spectral resolution and the hyperspectral sensor (ASD Field Spec® Pro) spans from 350 -2500 nm with fine resolution (1 nm). The CROPSCAN™ and hyperspectral sensors are depend on natural light thus called as passive sensors. For the ASD Field Spec® Pro artificial light using a 50W halogen lamp was used to obtain consistent illumination of the sample, using the same apparatus as Sanches (2010).

The mean reflectance of pasture canopy corresponding to each sensor visualized in Figure 1 resembles the typical reflectance of green vegetation.

After acquisition of spectra, the corresponding samples were clipped then harvested to ground level with hand-held cutters and prepared for laboratory analysis. The fine ground samples were analysed for CP, ADF, NDF, ME, ASH, Lignin, Lipid, OMD, DCAD and SSS using near-infrared reflectance spectroscopy - NIRS at FeedTECH (Corson, *et al.*, 1999) laboratory, Ag-Research in Palmerston North, New Zealand.

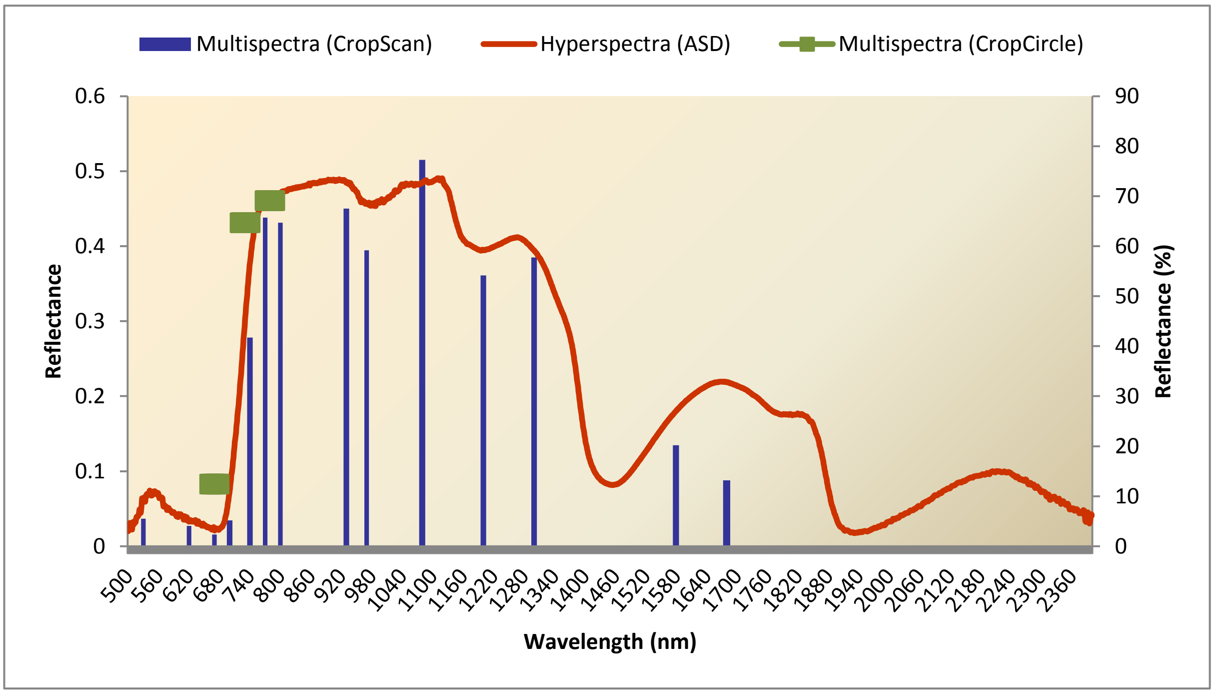

Figure 1 Pasture reflectance of multispectral (CROPSCAN and Crop Circle) and ASD Field Spec® Pro hyperspectral devices.

Data analysis:

Accurate quantitative estimation of vegetation biochemical variables is necessary for estimating crop health. In Figure 2, several approaches have been developed to build relationships between reflectance and properties of interest. These approaches include, statistical based (also called inductive), physical modelling (also called deductive), and integration of statistical and physical models, have been widely used. Each methodology presenting its own advantages and disadvantages.

Typically, statistical based approaches are used to analyse remote sensed data for estimating the vegetative characteristics such as, LAI, biomass and chlorophyll. The relationships between the spectral information (reflectance) and the biophysical and biochemical characteristics of vegetation were developed through a prescribed calibration and validation process where both univariate and multivariate statistical methods are involved. Univariate techniques are , usually used in association with sensors with fewer wavebands (1-3), and simulated into vegetation indices (Pullanagari, et al., 2009), used to establish the relationship between depend and independent variables.

By contrast, multivariate techniques have become available and capable of extracting greater extent information from spectral signatures to describe the vegetation parameters than univariate techniques. The multivariate analysis tools, stepwise multiple linear regression (SMLR), principal component regression (PCR), and partial least square regression techniques (PLSR), usually integrate information from several wavebands to elucidate the required vegetation characteristics.

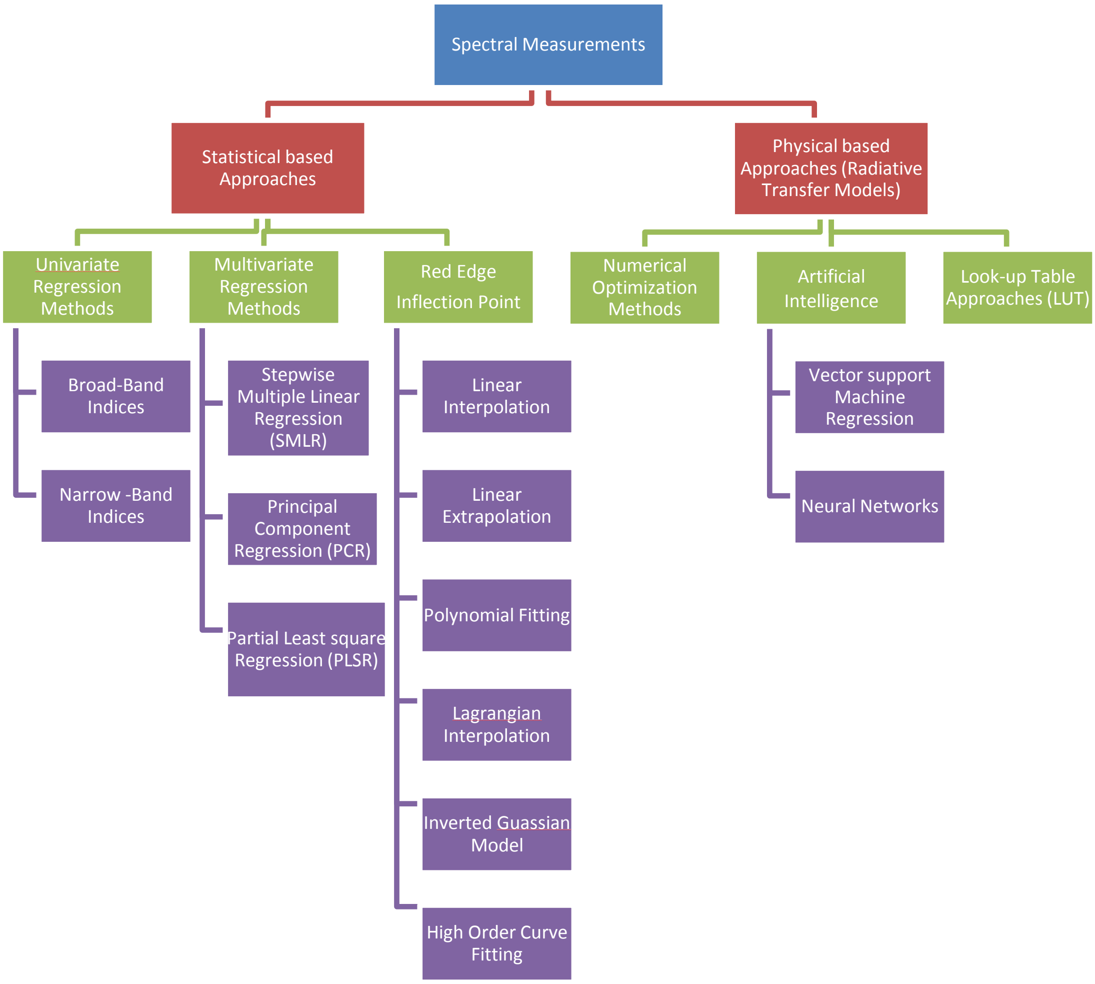

Figure 2 Classification of spectral measurement approaches

In this study, the reflectance data of CropCircle™ converted into normalized difference vegetation index (Rouse, *et al.*, 1974) by using the Equation 1 and regressed against reference values of nitrogen concentration.

$$\mathrm{NDVI} = \frac{(\mathrm{NIR}-\mathrm{VIS})}{(\mathrm{NIR}+\mathrm{VIS})} \quad (1)$$

Whilst, for multispectral (CROPSCAN™) and hyperspectral data multivariate statistics were applied by using partial least square (PLSR) algorithm.

Results and Discussion:

The association between NDVI which is derived from manipulation of reflectance data of CropCircle™ and reference values of nitrogen concentration is illustrated in Figure 3, higher r^2 value (0.76) was obtained. Similarly, a study in Western Australia demonstrated that plant growth rate (PGR) of pasture can be predicted at weekly intervals using NDVI, derived from MODIS imagery (Donald, *et al.*, 2010) and also recommended for making farm-management decisions. Trotter *et al* (2010) found that there was a strong correlation (r^2-0.77) between log-transformed soils adjusted vegetative index (SAVI) and green dry matter of pasture.

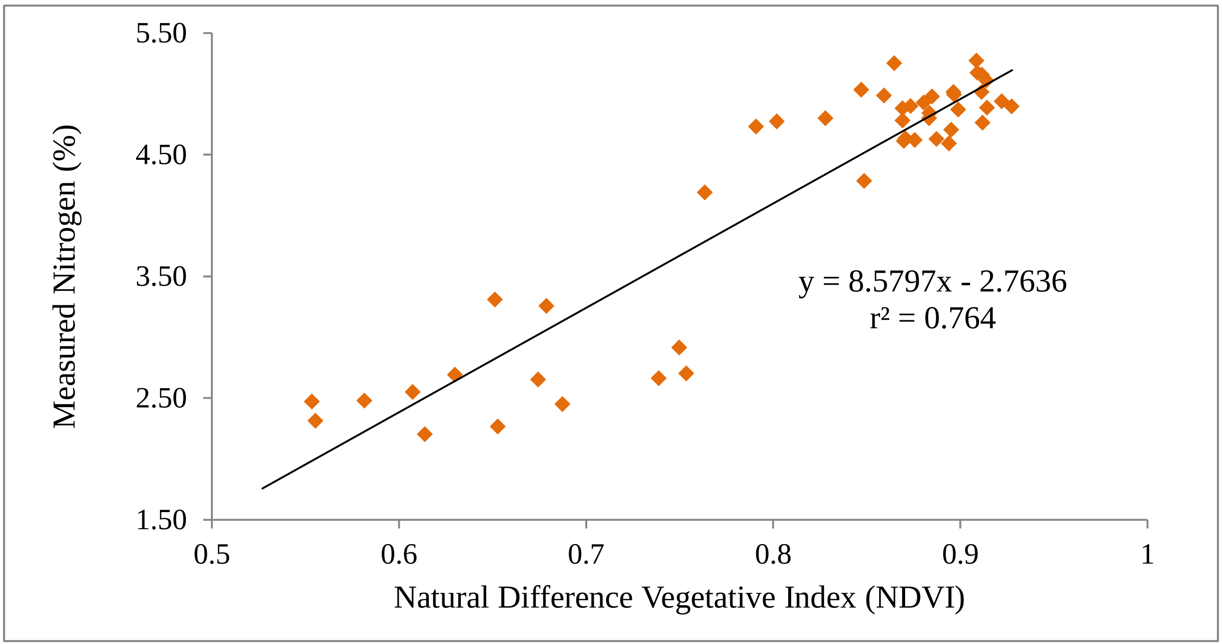

Figure 3 Regression model showing the relation between measured nitrogen and sensor (Cropcircle™) derived reflectance readings as natural difference vegetative index (NDVI).

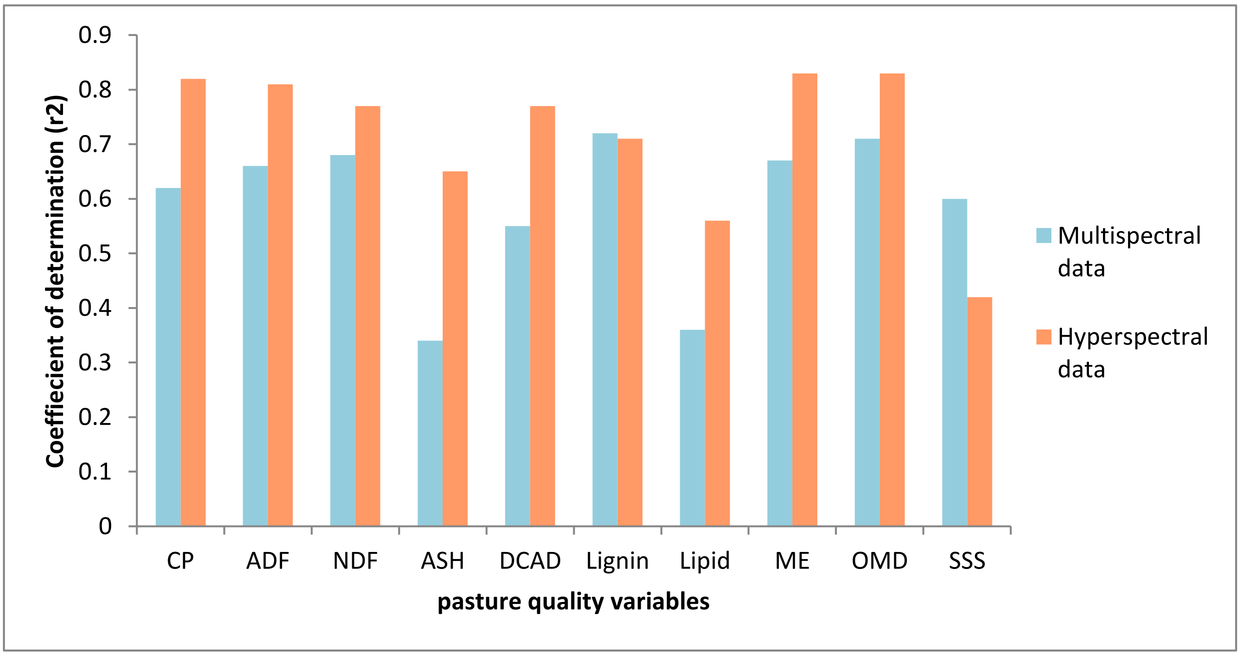

Figure 4 The r^2 values between pasture quality variables and reflectance data of CROPSCAN™ (multispectral data) and ASD Field Spec® Pro (hyperspectral data) using PLSR algorithm

The results from the analysis of multispectral sensor (CROPSCAN™) and hyperspectral sensor (ASD Field Spec® Pro) data were illustrated in Figure 4. Multispectral sensor predicted the quality parameters such as CP, ADF, NDF, lignin, ME, OMD and SSS with reasonable precision (r^2 = 0.60-0.72) but the parameters ASH, DCAD and lipid were predicted with lower r^2 values. However, the prediction performance of hyperspectral sensor was improved significantly; r^2 values ranged 0.65-0.83 while the quality parameter SSS predicted with lower precision (r^2 = 0.42). This indicates that when the spectral resolution of the sensor increases the precision to estimate foliar biochemical would be improves. Biewer et al., (2009) concluded in a statement that hyperspectral data of legume-grass mixtures has improved the precision and accuracy for predicting the quality components such as ASH, metabolisable energy, crude protein and acid detergent fiber by PLSR.

Conclusion:

The results from the experiment have explained the potential of proximal remote sensing devices for estimating the pasture quality components. Among the various optical sensors, hyperspectral sensor has provided highest precision in predicting the pasture quality. From this, we conclude that these instruments could be used by farm mangers as real-time information tools for optimising pasture management decisions. Creating a needs based N fertilizer programme which will assist in developing a better diet for dairy cows.

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