THE USE OF OPTICAL SENSORS TO ESTIMATE PASTURE QUALITY

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Abstract- Optical remote sensing tools are being used in a number of agricultural applications by recording an object's transmission of electromagnetic energy from reflecting and radiating surfaces. This unique spectral information is used to characterize the features of green vegetation. With the development of proximal sensing tools, vegetation or crop health can be determined and monitored in real-time. This information provides an opportunity for precise management of input resources to optimise plant growth and reduce the potential for an adverse environmental effect.

Pasture management is of major importance in New Zealand. This paper describes the operation of multispectral (Crop Circle™ and CROPSCAN™) and hyper spectral sensors (ASD Field Spec® Pro) to explore the pasture quality and quantity. The ability to manage these factors is an important component in grazing, livestock management, and a key driver of animal performance and productivity. The results indicate that these sensors have the potential to assess vegetation characteristics.

This paper presents the description of optical (multispectral and hyperspectral) sensors and the potential to estimate pasture quality, and outlines methods for developing robust relationships between spectral reflectance and pasture quality variables.

II. THEORETICAL BACKGROUND

The principle of optical remote sensing originated from spectroscopy, which is the study of the interaction between electromagnetic radiation and matter. In contrast to spectroscopy, remote sensing focuses on reflectance rather than absorbance.

According to the Beer-Lambert law [6], in Figure 1, when energy hits the object (leaf) it can be absorbed, transmitted and reflected. The fraction of energy reflected at a particular wavelength varies for different features. Additionally, the reflectance of features varies at different wavelengths. Thus, two features that are indistinguishable in one spectral range may be very different in another portion of the spectrum. Therefore, this essential property of matter allows different features to be identified and separated by their spectral signatures.
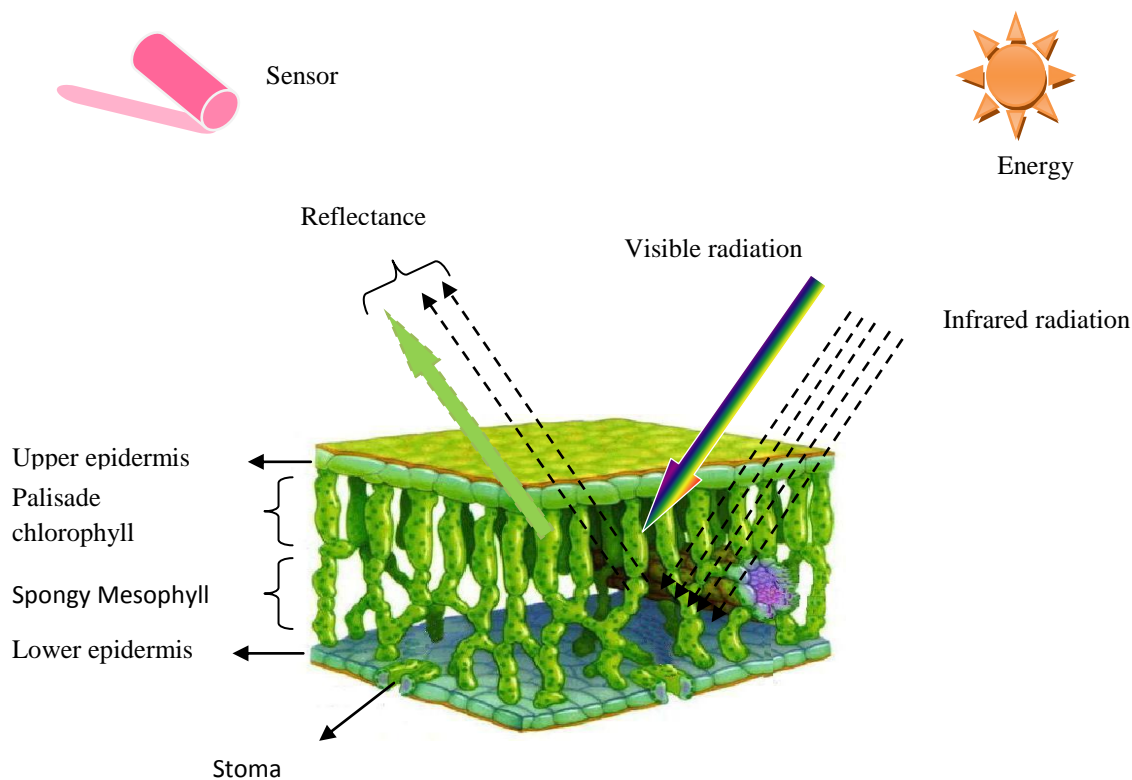

Figure 1. Interaction between energy source, leaf structure and spectral sensor [7].

The unique spectral signatures of green vegetation from visible region of the electromagnetic spectrum allow quantifying biomass, dry matter, chlorophyll, nitrogen and vegetative fraction etc. While infrared radiation of the electromagnetic spectrum is also responsible for determining the other biochemical concentrations. These infrared (near and shortwave infrared) signatures originates from the energy transition of the molecular vibration (rotation, bending and stretching) of the C-H, N-H, O-H, C-N and C-C bonds, which are the primary constituents of the organic compounds of plant tissues. Therefore, the reflectance from the infrared region is a function of chemical composition. For instance, Table 1 describes that each quality component has its own spectral signature as absorption peaks at specific wavelength [9].
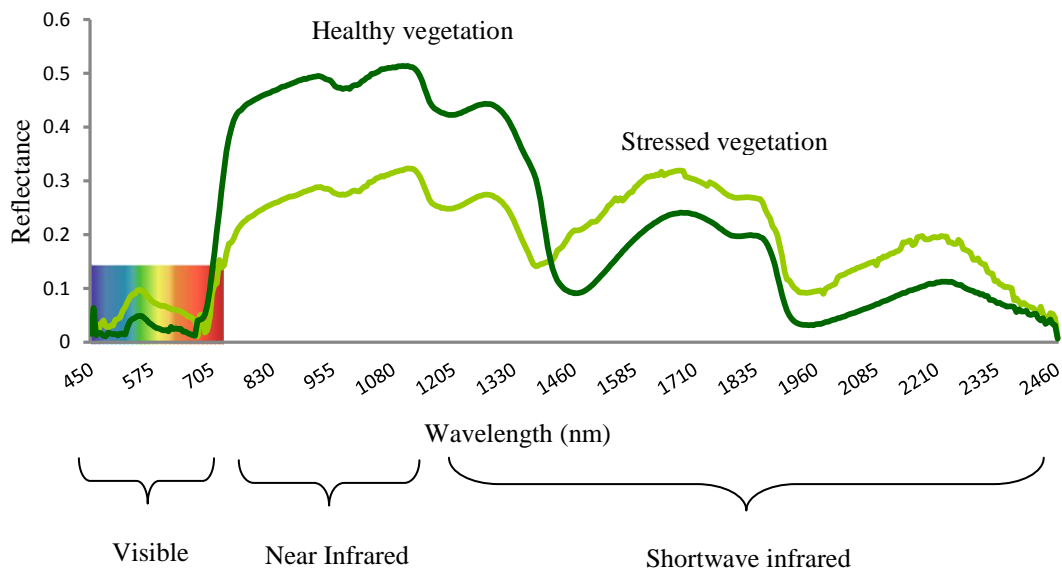

Figure 2. Reflectance of green vegetation across the electromagnetic spectrum [1].

III.   DESCRIPTION OF THE SENSORS

There are a wide range of optical sensors available, based on their spectral properties they classified as multispectral and hyperspectral spectral sensors.

A multispectral sensor (Crop Circle™ and CROPSCAN™) has wide spectral resolution with a limited number of wavebands used to describe a limited number of features such as nitrogen [10] and biomass variation, and leaf area index [11] while hyperspectral sensors such as the ASD Field Spec® Pro offer fine spectral resolution with numerous and contiguous wavebands across the electromagnetic spectrum which provides detailed information about the object such as detailed biophysical and biochemical information. The importance of high spectral resolution sensor in quantifying the various features with high precision and accuracy is highlighted in [12]. Based on the source of light, these sensors are classified into active and passive sensors. Active sensors such as the Crop Circle™ ACS-470 from Holland Scientific Inc., uses its own light source and can be used to collect data within a range of lighting conditions or even darkness making it much more usable to growers. In contrast, passive sensors, for example: CROPSCAN™ (Rochester, Minnesota), completely depends upon natural light (sun radiation) for radiant flux and used to collect information on the level of that varying natural light.

Table 2 describes the technical specifications of the multispectral and hyper spectral sensors which were used in this study. Investigating the spectral resolution and spectral range of the optical sensors was a critical component for the study because of each feature can be characterised by specific wavebands (Table 1) with optimum resolution.

S.No	Specification	Hyper Spectral Sensor	Multi Spectral Sensor	
1	Name	ASD Field Spec® Pro	CROPSCAN™	Crop Circle™
2	Sensor type	Passive	Passive	Active
3	Spectral range	350-2500	440-1680	450-880
4	Spectral Bands	2150	16	3
5	Spectral Resolution	1-2 nm	10 nm	10-20
6	Detectors	Silicon (300-1000nm) TE cooled, InGaAs (1000-2500 nm)	Silicon and Germanium	Silicon
7	Foot print	20 cm	60 x 60 cm	5×60 cm
8	FOV	8°,18°,25°	28°	32°/6°
9	Distance from target	1 m	1.2 m	0.6-1.2 m

Table 2. Sensor Specifications for example hyperspectral and multispectral sensors

Input data

Raw spectral data

Data Reduction

Reducing spectral resolution by averaging the subsequent wavebands

Data Transformation

Log and First derivative transformation

Smoothing

Using Savitzy-Golay filter the noise is eliminated which is deposited across the electromagnetic spectrum

Mean centring the spectral data

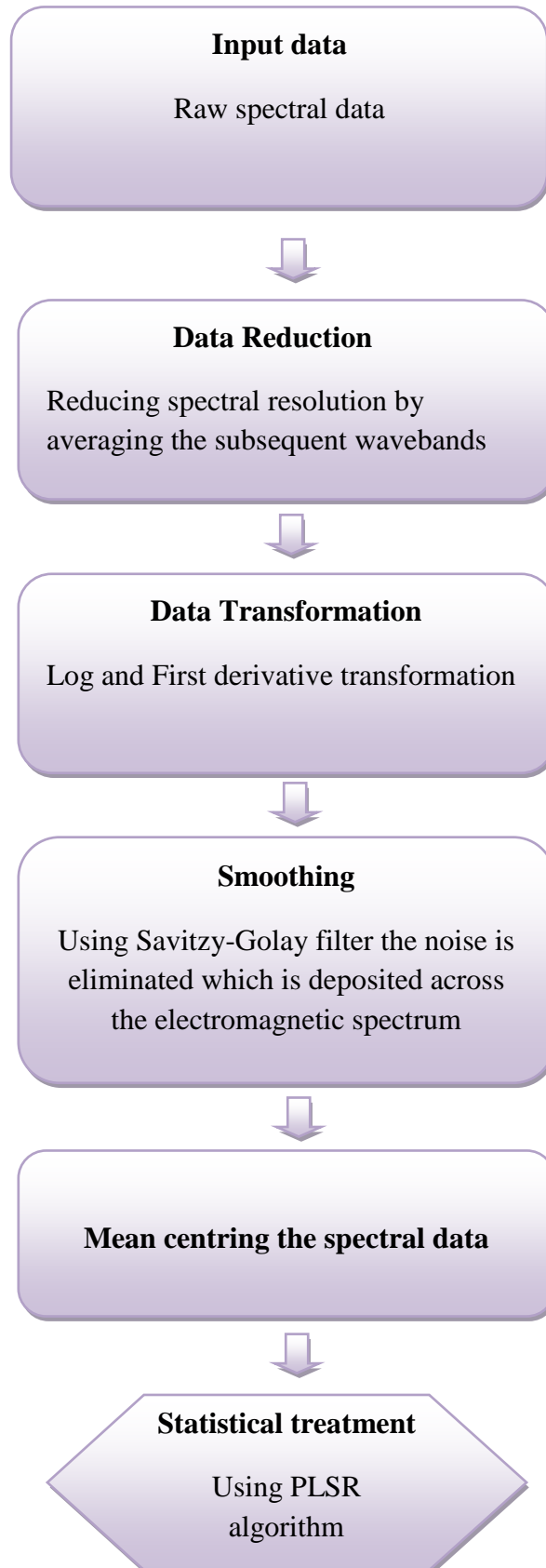**Statistical treatment**

Using PLSR algorithm

Figure 4. Flow chart of hyperspectral data analysis

canopy pasture probe (CAPP)-top grip coupled with 50 Watt tungsten-quartz-halogen lamp [18].

After obtaining spectral signatures, concurrent ground truth samples were harvested and then immediately sent to the FeedTech (AgResearch Grasslands, Palmerston North) laboratory for near infrared spectroscopy analysis which is used extensively for determining chemical composition of dried ground samples.
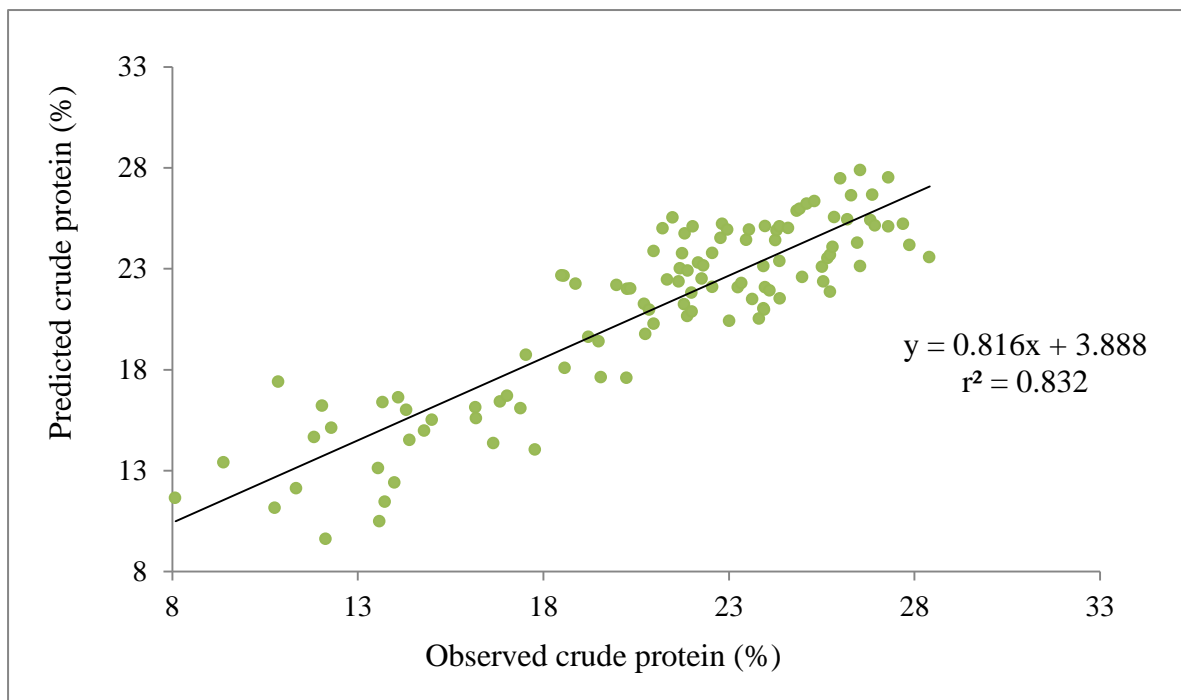

Figure 6. Scatter diagram showing the relation between observed and predicted observations [19]

Prior to data analysis the data manipulations steps illustrated in Figure 3 were used to process the data, PLSR algorithms were then applied for statistical analysis. Then as part of the calibration of the model the measured crude protein concentrations were plotted against the predicted levels, satisfactory results were obtained with an r^2 value of 0.832. The prediction accuracy of the hyperspectral sensor is greater than the multispectral sensor and wide had wide range of applicapability.

VI.   CONCLUSION

VIII.   REFERENCES

[1]   MAF. (2003, *Contribution of the Land-based Primary Industries to New Zealand's Economic Growth*. Available: http://www.maf.govt.nz/mafnet/rural-nz/profitability-and-economics/

[2]   C. W. Holmes*, et al.*, *Milk production from pasture*. Palmerston North, N.Z. :: Butterworths of New Zealand Ltd., 2002.

[3]   R. Houborg and E. Boegh, "Mapping leaf chlorophyll and leaf area index using inverse and forward canopy reflectance modeling and SPOT reflectance data," *Remote Sensing of Environment,* vol. 112, pp. 186-202, 2008.

[4]   J. L. Hatfield*, et al.*, "Application of Spectral Remote Sensing for Agronomic Decisions," *Agronomy Journal,* vol. 100, 2008.

[5]   E. R. Hunt*, et al.*, "Applications and Research Using Remote Sensing for Rangeland Management," *PHOTOGRAMMETRIC ENGINEERING AND REMOTE SENSING,* vol. 69, pp. 675-694, 2003.

[6]   P. Williams and K. Norris, *Near-infrared technology in the agricultural and food industries*. MN 55121, USA: American Association of Cereal Chemists, Inc., 1987.

[7]   Drew, "Leaf structure," in *https://dbscience3.wikispaces.com/Drew*, ed.

[8]   Y. Ozaki*, et al.*, "Spectral analysis," in *Near infrared spectroscopy in food science and technology*, Y. Ozaki*, et al.*, Eds., ed New Jersey: Wiley-Interscience, John Wiley & Sons, Inc.: Hoboken 2005.

[9]   O. Mutanga, "Hyperspectral remote sensing of tropical grass quality and quantity," PhD, Wageningen University, Wageningen, The Netherlands, 2004.

[10]   D. Roberts*, et al.*, "Optimization of Crop Canopy Sensor Placement for Measuring Nitrogen Status in Corn," *Agronomy Journal,* vol. 101, p. 140, 2009.

[11]   R. Darvishzadeh*, et al.*, "Hyperspectral vegetation indices for estimation of leaf area index," in *Remote Sensing: From Pixels to Processes*, Enschede,Netherlands, 2006.

[12]   G. Chattopadhyay, "Sensor technology at submillimeter wavelengths for Space Applications," *International Journal on Smart Sensing and Intelligent Systems,* vol. 1, pp. 1-20, March, 2008.

[13]   J. R. J. Jungho Im, "Hyperspectral Remote Sensing of Vegetation," *Geography Compass,* vol. 2, pp. 1943-1961, 2008.

[14]   R. R. Pullanagari and I. Yule, "Use of Reflectance Sensors to Optimise Nutrient Management," in *Nutrient Management in a Rapidly Changing World*, Palmerston North, New Zealand, 2009, pp. 70-79.

[15]   J. Rouse*, et al.*, "Monitoring the vernal advancement and retrogradation (green wave effect) of natural vegetation.," Greenbelt, Md, USAOctober 1973 1974.

[16]   M. Lieschnegg*, et al.*, "Non-invasive characterization of total hip arthroplasty by means of passive acceleration measurement," *International Journal on Smart Sensing and Intelligent Systems,* vol. 3, pp. 75-87, March, 2010.

[17]   R. A. Viscarra Rossel, "ParLeS: Software for chemometric analysis of spectroscopic data," *Chemometrics and Intelligent Laboratory Systems,* vol. 90, pp. 72-83, 2008.

[18]   I. D. Sanches, "Hyperspectral Proximal Sensing of the Botanical Composition and Nutrient Content of New Zealand Pastures," PhD, Soil and Earth Sciences, Massey University, Palmerston North, New Zealand, 2010.

[19]   I. J. Yule*, et al.*, "Technologies to improve productivity and reduce environmental impact of dairy systems," presented at the EcoTechs Conference: International workshop:Eco-design Methods and Tools for Agricultural Technologies, Clermont-Ferrand, France, 2010.