



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.

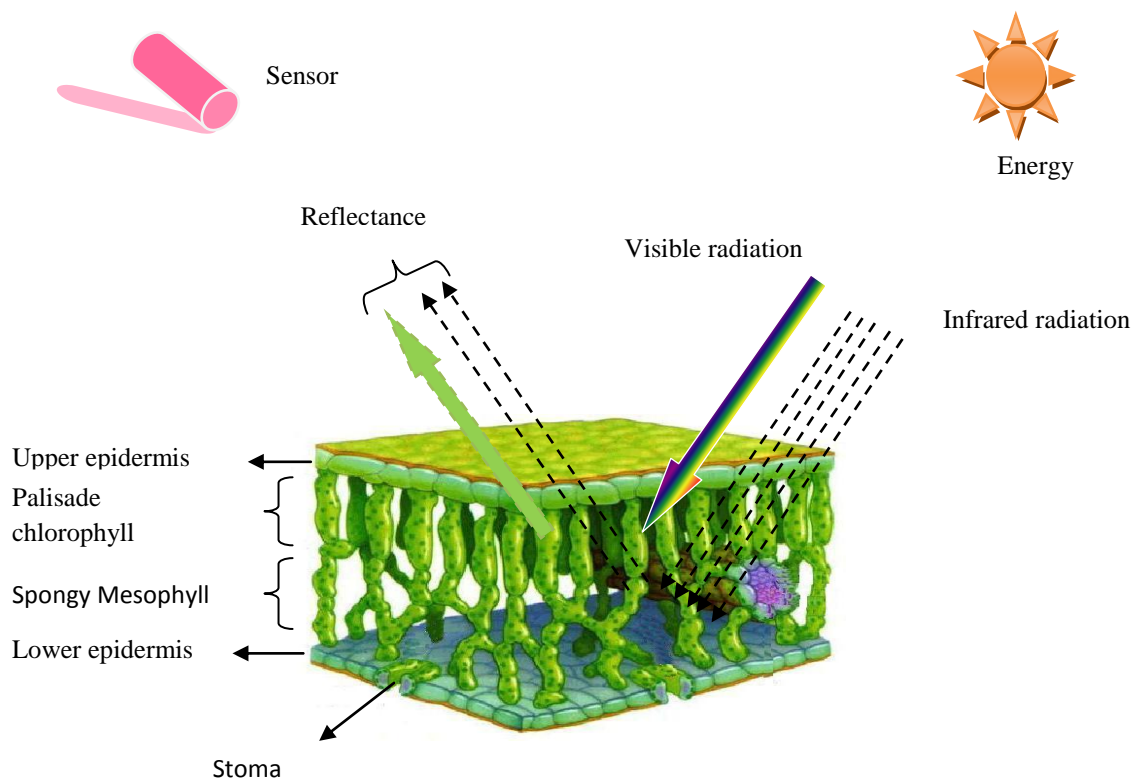


Figure 1. Interaction between energy source, leaf structure and spectral sensor [7].

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].

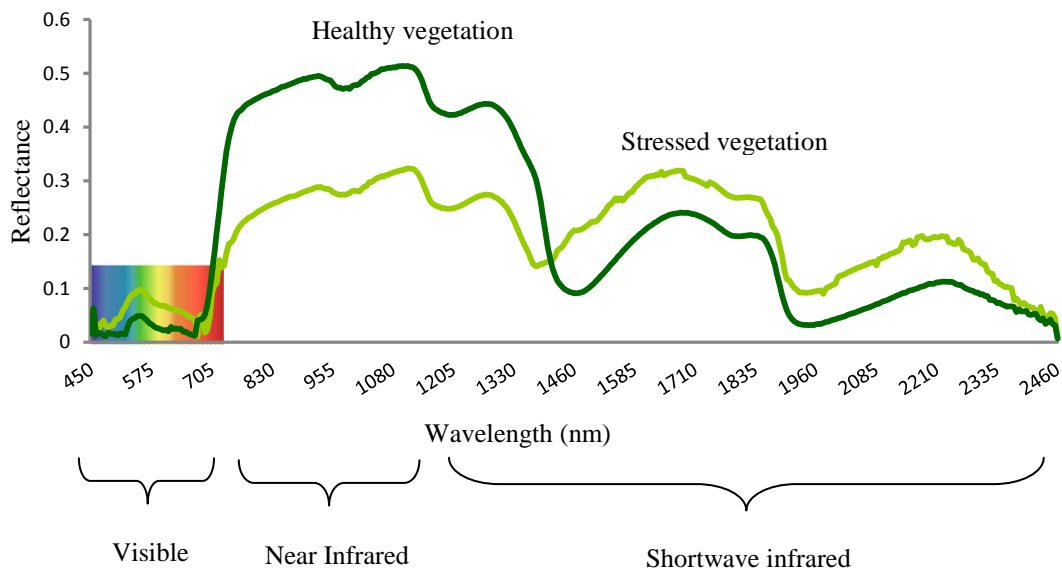


Figure 2. Reflectance of green vegetation across the electromagnetic spectrum [1].

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

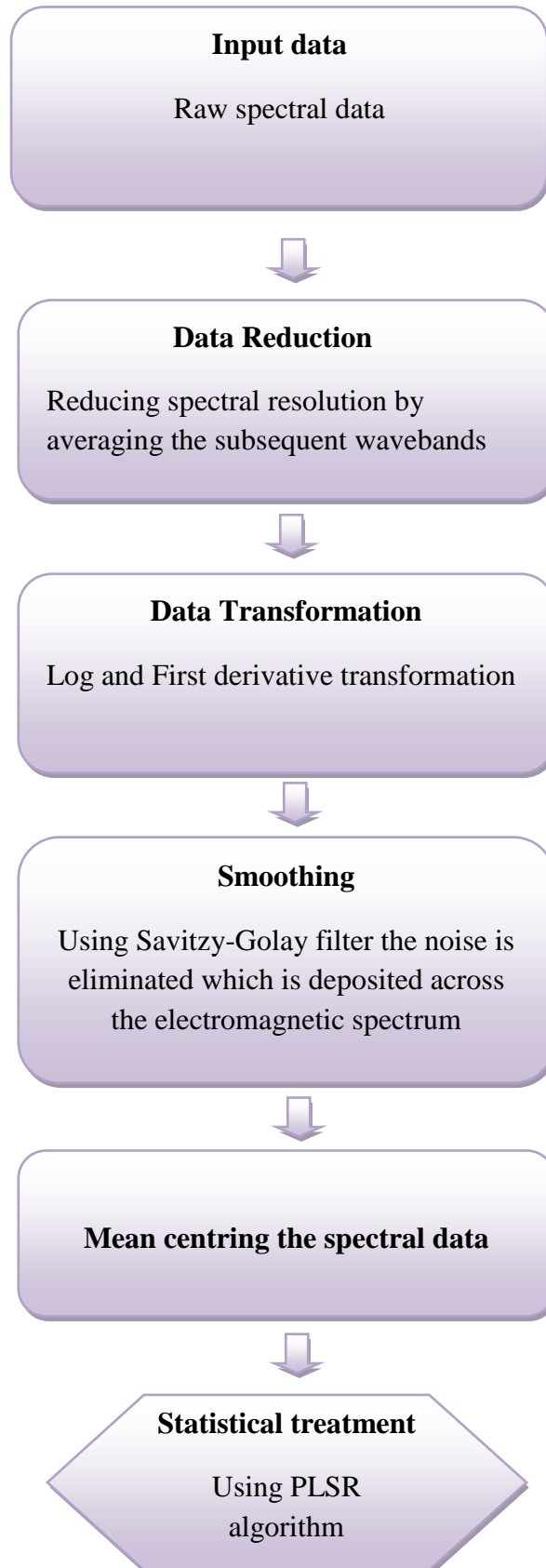


Figure 4. Flow chart of hyperspectral data analysis

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.

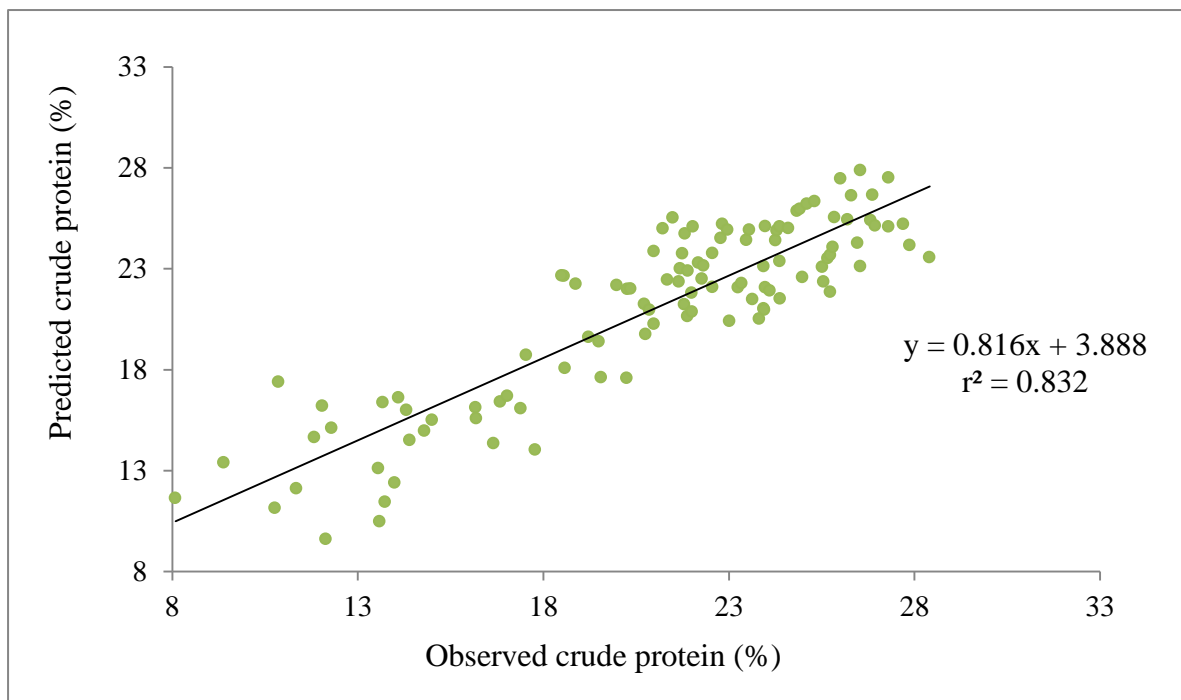


Figure 6. Scatter diagram showing the relation between observed and predicted observations [19]

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 applicability.

VI. CONCLUSION

These research findings demonstrate that there is potential in using optical sensors to provide a practical solution for providing greater accuracy in pasture quality measurement in the field. This takes optical technology out of the laboratory and onto the farm to give near real-time information to the farmer. When proximal sensors are coupled with global positioning system (GPS) pasture quality spatially can be monitored spatially which allows the relationships between environment and production inputs such as fertiliser to be further optimised. This is currently possible with a small range of sensors using two or three channels to estimate crop biomass in crops such as wheat, the information from these sensors is used to make decisions around the fertiliser application to the crop. The advantage of crops such as wheat is the paddock is usually around the same growth stage, weeds are suppressed and so variability is limited. In pasture the situation is somewhat different; the pasture has been subject to grazing and highly variable (N) application through urination events from cows, in addition to other environmental factors relating to topography and soil. The maturity of the sward also changes throughout the year, as does species composition, and calibrations achieved at one part of the season may not be relevant to later stages. Clearly further work needs to be completed to establish robust calibration models and methodologies to operate over a range of conditions.

If this technology were applied to pasture management, the results from pasture measurement would make a significant difference to farmer's decision making on such issues as fertilizer application, pasture and grazing management. This should lead to better productivity for farmers but also better environmental outcomes as a result of reduced error margins in current farm practices and better informed management decisions.

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