Assessing Crop Vigor From High Spatial and High Spectral Optical Imagery

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***Abstract* – Early detection of crop stress and estimates of crop biomass allow agricultural producers to implement the necessary steps to mitigate against crop infestations or to boost yields in areas of lower productivity. The Canada Centre for Remote Sensing has been involved in a multi-year project to determine the information content in high spatial and high spectral data sets for use in precision agriculture. Early results indicate that several indicators of crop vigor are significantly correlated with pseudo-reflectance values.**

1. INTRODUCTION

Within the Applications Division of the Canada Centre for Remote Sensing (CCRS), research is being conducted to evaluate the role of remote sensing in precision agriculture. Although the corner stone of precision agriculture is the use of georeferenced data layers for managing crops on a site specific basis, such a system requires repetitive data input related to the spatial variability of field conditions. A number of high spatial visible near-infrared (VNIR) satellites are scheduled for launch over the next few years. With the frequent revisit schedule of this constellation of satellites, and the dependence of reflectance on a number of crop characteristics, remote sensing will become an important source of data.

The use of data layers in guiding variable rate applications suggests that the data derived from remote sensing must have high geometric locational accuracies. In addition, algorithms developed to extract crop parameters from reflectance, as well as the requirement for monitoring crop condition over time, dictates that data must be radiometrically and atmospherically correct.

In 1996 and 1997, CCRS collected airborne *casi* (Compact Airborne Spectrographic Imager) data over sites in southern Manitoba. Analysis of the 1996 data indicated that near infrared (NIR) reflectance was sensitive to crop biomass variability across canola fields (Brown *et al*., 1997). This paper describes early results from the 1997 *casi* data.

2. METHODOLOGY

The 1997 study site was centered on the town of Carman (98°00’ W longitude, 49°30’ N latitude), located in southern Manitoba. The site covers an area of approximately 10 km (north-south) by 30 km (east-west). Both sandy and heavier clay soils are found across the site and this soil mix is reflected in a diversity of agricultural crops including wheat, barley, oats, flax, canola, corn, beans, peas, potatoes and sunflower.

From July 15-17, both spatial mode (19 bands; 455 nm to 940 nm) and spectral mode (96 bands; 400 nm to 960 nm) *casi* data were gathered over the Carman site. In both modes, imagery was collected at a 4 metre x 4 metre ground resolution. During the week of the *casi* over flights field crews collected information on crop growth across 12 pre-selected fields. On each of the 12 fields, transects were planned across the fields, along which sample sites were located. Where applicable, imagery was used to plan transects according to management zones and in the case of variable treatment applications, transects were planned to capture samples within each treatment zone. In general, 8-12 sample sites were located in each field. The location of all within-field sample points and treatment locations were recorded using an Omnistar differential GPS. Also, during the first week of June, GPS points were collected at a sample of road intersections across the site, as input into image geocoding. Positional accuracies for this GPS model are generally within an image pixel (less than 3-5 metres in the XY direction, 95% of the time).

At each sample point along the transect, a number of specific measurements and samples were gathered:

(1) Biomass: At each site, a 0.5 x 0.5 m sample of above ground crop was cut and placed in a plastic bag. Biomass samples were weighed wet, in the field, and then transported to the University of Manitoba where they were oven dried and re-weighed. Plant water content (PWC) was calculated using:

$$[(wet\ biomass(g) - dry\ biomass(g)) / wet\ biomass(g)] * 100$$

(2) Leaf Area (LA): A subsample of plant biomass was used to calculate leaf area. LA is recorded in cm^2.

(3) Plant chlorophyll: At each site within a field, 6-10 chlorophyll measurements were made using a chlorophyll meter. These measurements were taken on upper leaves within the crop canopy. The chlorophyll meter records plant chlorophyll content as a relative value between 0 and 50. Higher chlorophyll contents are represented by higher chlorophyll values. The 6-10 measurements were averaged to provide a mean chlorophyll measurement per sample site.

(4) Crop height: At each site, crop height was recorded in cm.

(5) Vertical photos above the crop canopy recorded percent ground cover.

(6) Plant and soil spectra were gathered at some biomass sample points, using the GER3700 spectrometer (350-2500 nm).

Using the *casi* navigation data, in-flight GPS data, ground GPS points and cross flight lines, each of the 9 spatial mode flight lines will be geometrically corrected using an in-house CCRS program called GEOCOR (Bannari *et al*., 19930. The first flight line has been corrected using this program, with locational accuracies of approximately 1.4 m along track and 6.6 m across track.

A potato field (approximately 220 acres) which had received different nitrogen treatments was located on this first flight line and results from the analysis of this field are presented in this paper. GPS sample point locations were overlayed on the *casi* imagery and average radiance was extracted for a 3 x 5 pixel area centered on each of the 24 sample points. Radiance values for the potato crop were normalized for a first-order removal of atmospheric effects using the flat-field approach (Roberts *et al.*, 1986). Each pixel value in each band was divided by the corresponding radiance of the road's asphalt surface (spectrally flat target). The resulting values, pseudo-reflectances, were then multiplied by 100.

3. RESULTS

Pseudo-reflectance values for each of the sample points are graphed in Fig. 1. Large variations in near-infrared reflectances are observed, with lower reflectance values corresponding to poorer growth areas. For this potato field, poorer growth areas have a larger contribution to reflectance from the soil.

To determine the relationship between reflectance and crop characteristics, pseudo-reflectances from individual bands were regressed against ground measurements (N = 24). As well, red (620 nm) and near-infrared (794 nm) bands were used to create an NDVI image, and a Modified Simple Ratio (MSR) (Chen, 1996). Output from these ratios was also correlated with ground data (Table 1).

TABLE 1
CORRELATION COEFFICIENTS (R^2) FOR POTATO FIELD

Simple Linear Regression (R^2 Values)				
	Red (620 nm)	Near-IR (794 nm)	NDVI	MSR
Crop height	.275	.373	.388	.540
Wet biomass	.187	.508	.412	.520
Dry biomass	NS	.245	.213	.244
LA	.268	.506	.318	.543
PWC	.220	.621	.546	.575
Multiple Linear Regression (R^2 Values)				
	Red (620 nm)	Near-IR (794 nm)	NDVI	MSR
Crop height & PWC	.483	.806	.642	.665

NS = not statistically significant at a probability of < 0.05

Pseudo-reflectances for the single near-infrared band correlate well with several simple indicators of crop vigor, including wet biomass, leaf area and percent water content. The Modified Simple Ratio provides results similar to the single NIR band, but correlation coefficients are higher than those for the NDVI. A number of the simple regression equations using the NIR band and the MSR were inverted and applied to the image. This process created thematic maps which indicated predicted wet biomass, leaf area, percent water content and crop height. No independent measurements were available to establish the accuracy of the map, but areas of good growth and poorer growth, as observed in the field, were delineated on the maps.

Correlations between pseudo-reflectances and indicators of crop growth were poorer for the potato crop when compared with correlations for the canola crop in the Altona data set (Figs. 2 and 3). The contribution of soil to reflectance is significantly greater for row crops such as potatoes, where only part of the area is covered by crops. This mixture of signals from the soil and the crop is likely contributing to the lower correlations.

The complexity of agricultural targets suggests that several crop parameters are likely affecting total reflectance. Consequently, a multiple regression was performed, incorporating two indicators of crop vigor – crop height and PWC. As expected, regression coefficients significantly improved (Table 1).

4. CONCLUSIONS

The Canada Centre for Remote Sensing has been involved in a multi-year project to determine the information content in high spatial and high spectral data sets for use in the site specific management of agricultural fields. During both 1996 and 1997, *casi* was flown over sites across southern Manitoba. Preliminary analysis of the 1996 and 1997 data indicated that the *casi* data were sensitive to indicators of crop vigor across canola and potato fields. Several simple indicators of crop vigor – including wet biomass, plant water content and crop height were significantly correlated with pseudo-reflectances. Although relationships established through statistical analysis tend to be site specific, these preliminary results demonstrate that within-field crop variability can be related to high spatial VNIR imagery. Further analysis of this data set is planned, including analysis of the remaining sampled fields for both the spatial and spectral mode data.

5. REFERENCES

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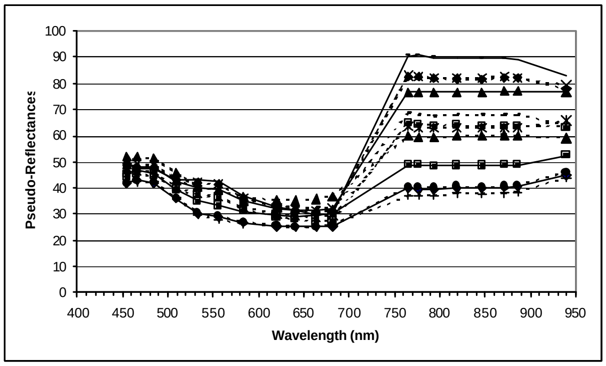

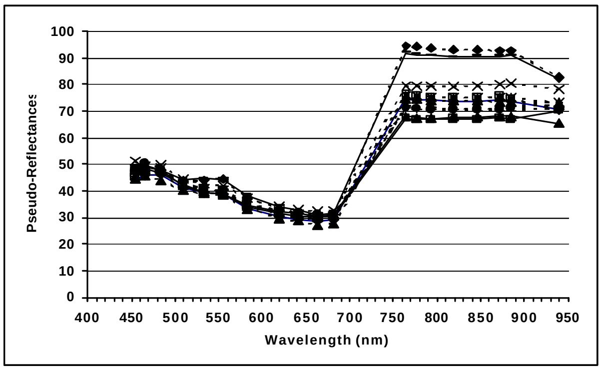

Fig. 1. Pseudo-reflectance values for the Carman potato field (24 sites graphed). The first plot graphs sites 1-12 and the second plot graphs sites 13-24.

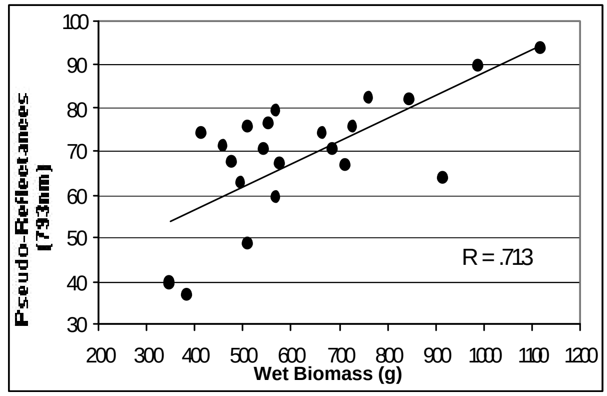

Fig. 2. Pseudo-reflectance values associated with wet biomass from the potato field (Carman, 1997)

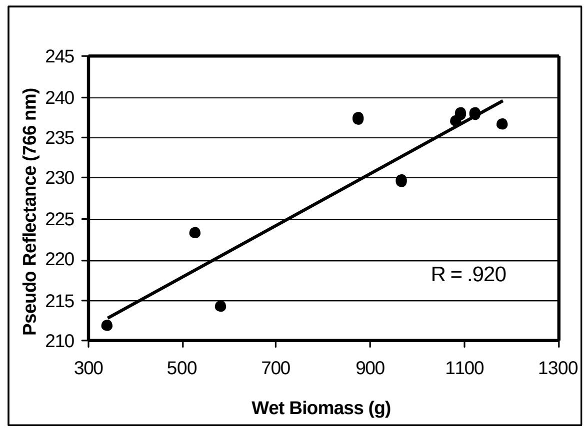

Fig. 3. Pseudo-reflectance values associated with wet biomass from the canola field (Altona, 1996)