COMPACT AIRBORNE SPECTROGRAPHIC IMAGER (CASI) USED FOR MAPPING LAI OF CROPLAND*

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ABSTRACT

During the BOReal Ecosystem-Atmosphere Study (BOREAS), which took place in Saskatchewan and Manitoba in 1994 and 1996, the Compact Airborne Spectrographic Imager (CASI) acquired images of different surfaces including croplands and boreal forests. In this paper, we present an analysis of CASI data against ground measurements of leaf area index (LAI) for croplands. Processed individual CASI bands from different crops and fields are combined and show that: (1) the blue band reflectance of cropland decreases with LAI; (2) the red band reflectance shows a weaker and more scattered decreasing trend with LAI than the blue band; and (3) the near-infrared (NIR) band reflectance reaches a plateau at a LAI of one. It is also shown that the response of vegetation indices based on the red and NIR bands, such as the Normalised Difference Vegetation Index (NDVI), to LAI is weak, although the Simple Ratio shows a stronger, but more scattered, linear increase with LAI than the NDVI. Comparisons with similar studies of vegetation indices and LAI for cropland and forested areas are presented.

1.0 INTRODUCTION

The leaf area index (LAI), defined as one half of the total foliage area per unit surface area (Chen and Black, 1992), is an important quantitative parameter needed in climate and ecology studies. Remote sensing can play an important role in the mapping of LAI (Chen and Cihlar, 1996), especially over large and unreachable areas. To map LAI, the relationship between spectral data and the ground LAI has been actively investigated over the years. To assess the reliability of relationships between remote sensing data and ground truth LAI, airborne sensors such as CASI with a high resolution, which allows a very accurate co-registration between the ground truth LAI and the remote sensed

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reflectances, is an asset. Using this very accurate spatial matching, CASI reflectances in three spectral bands are compared to LAI measured in 15 fields. The response of vegetation indices based on the red and near-infrared are then analysed and two LAI maps based on the normalised difference vegetation index (NDVI) and simple ratio (SR) are presented.

2.0 CASI MEASUREMENTS

The methodology for transforming the raw CASI digital numbers into apparent surface reflectances was described in previous studies (Chen et al., 1999; Gray et al, 1997). The Canadian Advanced Modified 5S (CAM5S) (O'Neill et al., 1996 and 1997) was used for atmospheric corrections. In this study, CASI was used in its spatial mode with a ground resolution of 2x4 m^2 re-sampled at 2x2 m^2, a swath of about 2000 m, and 15 spectral bands. Three bands are analysed in this paper: band 2 centred at 443 nm (blue); band 7 centred at 665 nm (red) and band 13 centred at 800 nm (near-infrared). The cropland transect (north south) of about 18 km is from the southern study area of BOREAS near Albertville, Saskatchewan. The image was geometrically corrected for the flight variations and geographically coded for co-registration with the LAI measurements.

3.0 LAI MEASUREMENTS

Relationships between LAI and vegetation indices for cropland have been extensively studied Photogrametric (Holben et al., 1980) based data, radiometric data, (Aase et al., 1985) and digital imagery (Hatfield et al., 1983) in the red and near-infrared have been widely used to relate LAI to vegetation indices. During the BOReal Ecosystem-Atmosphere Study (BOREAS), field measurements of LAI were acquired for forests and croplands using different methods employing the LAI-2000, TRAC, hemispherical photographs, and allometry. Studies have shown how the LAI is related to vegetation indices based on reflectance of CASI airborne (Chen et al., 1999) and space-borne remote sensing data (Chen and Cihlar, 1995; Chen 1996) of boreal forests. In this study, the Li-Cor LAI-2000 was used along two 50 m transects arranged in "+" shape to measure the LAI at 15 sites, along the swath of the CASI footprint over different croplands: barley, canola, pea, soybean and wheat on July 12, 1996. A GPS was used to find the exact positions where the LAI measurements were made and an average of the pixels in squared areas of 50x50 m^2 around the centre of the transects were done for the extraction of the reflectances.

4.0 RESULTS

Satellite vegetation indices have historically been measured with the red and near-infrared bands because, among many reasons, the AVHRR sensor used to globally estimate vegetation indices only has these two bands available in the optical range. Although satellites like the LANDSATs have other bands available such as the blue band, the amount of Raleigh scattering makes that band difficult to use. Airborne data are usually less affected by the atmospheric scattering since the optical path of the reflected radiation back from the target is much smaller than that of satellite. The three band reflectances, taken with CASI, are compared LAI ground measurements. Figure 1a shows that the blue reflectance decreases with LAI. The reflectance in the red band shown in Fig. 1b also exhibits a decreasing trend, but the datapoints are more scattered than in the blue band. The near infrared reflectances are found scattered evenly between 30% and 50%, except for the low LAI value. The increasing trend between very small LAI and the higher LAI is opposite to that measured in boreal forests (Chen et al, 1999). In a black spruce forest, it was found that the near-infrared reflectance decreases with LAI ranging between 0 and 5.

The ratio of near infrared and red band reflectances has been used under many forms as vegetation indices. Figure 2a shows how the red and near infrared are related to each other. We can see segregation by crop types on this plot: barley and wheat forming a group, pea, soybean and canola forming other groups. Previous studies showed that the simple ratio (SR = NIR/RED) is often the more sensitive to the variation in vegetation (Chen 1996). Figure 2b shows the LAI variation with the Normalised difference vegetation index (NDVI = NIR-RED)/(NIR+RED) and Fig. 2b the simple ratio. The NDVI plot shows no clear segregation. The two lines in Fig. 2c are exponential fits of the form NDVI = A*(1-exp(-B*LAI)) + C) applied to the NDVI-LAI points. The dashed line represents a fit made without the arrowed point. This point is marked because of its effect on the SR-LAI relationship. For NDVI-LAI relationship, the effect of using or not this point was not significant. In both cases, the r^2 was about 0.9. The high NDVI-LAI r^2 is found because of the low LAI point. Without this point, the exponential fit gives a r^2 of 0.17.

Linear regressions were performed on the SR-LAI points in Fig. 2.c. The arrowed point is more important in the fits of SR-LAI. With the point the regression gave a $r^2 = 0.24$, but without it $r^2 = 0.52$. The scattering of the datapoints may be cause by either different background soil, or the specific reflectivity of the different crops. Although the respond is more pronounced with the SR-LAI relationship, the higher correlation of NDVI-LAI would seem more appropriate to estimate the LAI of the scene. The NDVI-LAI relationship has a saturation problem that forced all field with high NDVI (>0.86) to have the same LAI (Fig 3a). Figure 3b shows the LAI map made from the SR-LAI fit (using 14 of the 15 points). Individual fields can be easily distinguished and the LAI shows some variations within each field.

5.0 CONCLUSION

The poor sampling of low LAI fields induces uncertainties in the relations found in this paper since the trends found were highly dependant on a single soybean measurement, although a similar study performed with soybean showed very similar NDVI and SR relationships to LAI (Holben et al, 1980). The blue band decrease in reflectance should be investigated more for its potential in airborne LAI retrieval. Crop types segregation was found to be a lot less important in the NDVI-LAI relationship and somewhat less important in the SR-LAI than forest types. The NDVI-LAI relationship gave a very good regression with $r^2 = 0.9$ but with a saturation for NDVI larger than 0.86. The lack of LAI measurements in the fields where the NDVI was higher than 0.86 makes it difficult to verify exactly at what value the NDVI saturates. However, natural variations within a given field at the 2x4 m^2 resolution are expected and only the map made with the SR-LAI relationship shows such variations. The stronger response of SR to LAI, although more scattered, is probably more appropriate than NDVI in LAI mapping of cropland.

5.0 REFERENCE

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6.0 FIGURES

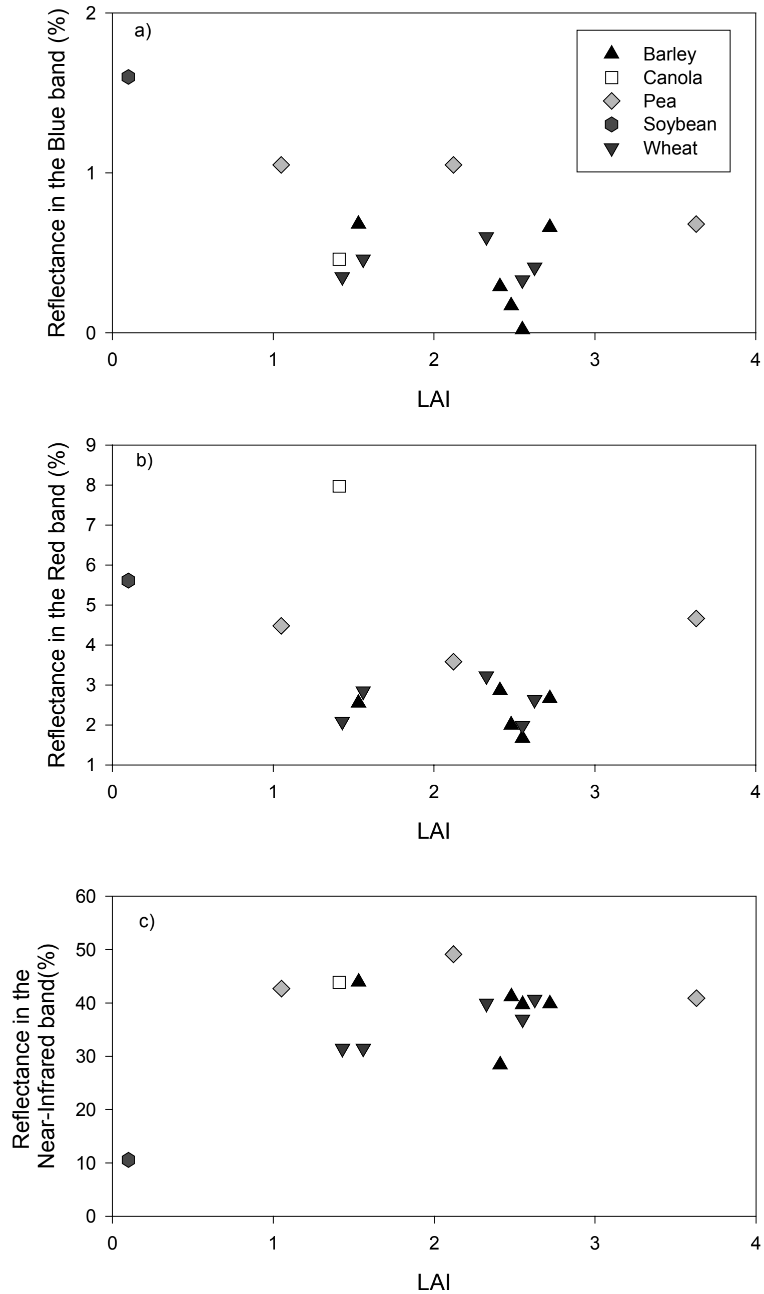

Figure 1: Blue (a), red (b) and near-infrared (c) reflectance response to change in leaf area index for different crops

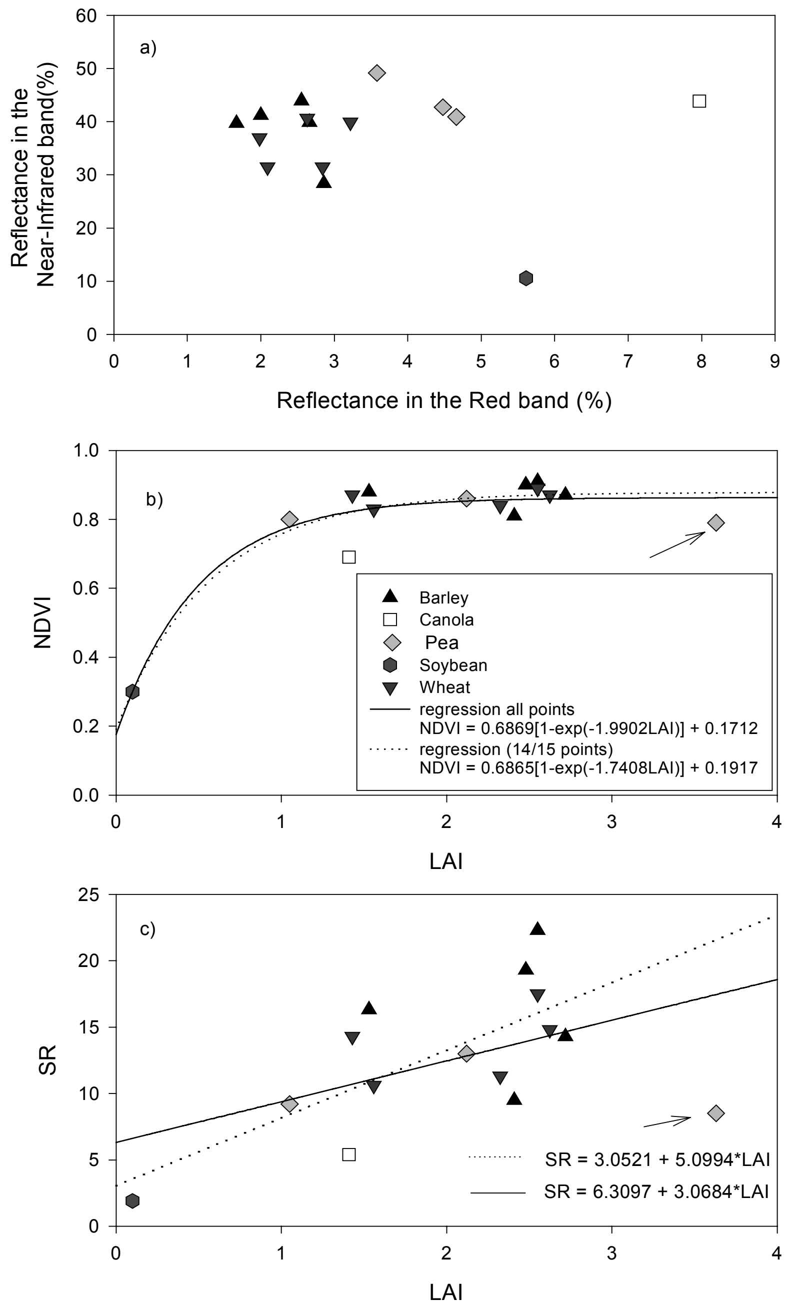

Figure 2: a) relationship between red and near-infrared reflectance, b) relationship between NDVI and lai, and c) relationship between simple ratio (SR) and LAI for different cropland.

Black LAI = 0
White 4<LAI < 5

Figure 3: CASI LAI image of cropland from the southern study area of BOREAS, located near Albertville, Saskatchewan. The LAI is based on (a) NDVI-LAI and (b) SR-LAI relationships found from a correlation between ground LAI measurements and CASI data.