Title:

Determining Density of Maize Canopy:

II. Airborne Multispectral Scanner Data[1]

by

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ABSTRACT

Multispectral scanner data were collected in two flights over a light colored soil background cover plot at an altitude of 305 m. Energy in eleven reflective wavelength bands from 0.45 to 2.6 μm was recorded by the scanner. Four growth stages of maize (Zea mays L.) were present at the time of each overflight, giving a wide range of canopy densities for each flight date. Leaf area index measurements were taken from the twelve subplots at the time of each overflight, and were used as a measure of canopy density.

Ratio techniques were used to relate uncalibrated scanner response to leaf area index. The ratios of scanner data values for the 0.72 to 0.92 μm wavelength band over the 0.61 to 0.70 μm wavelength band were calculated for each plot. The ratios related very well to leaf area index for a given flight date but could not be generalized between data from different flights because of uncertainty in scanner response on different dates. The results indicated that spectral data from maize canopies could be of value in determining canopy density.

Additional Key Words: ground cover, leaf area index, remote sensing.

INTRODUCTION

Airborne multispectral scanner data provide an extended view of the reflective properties of plant canopies. Information may be obtained in the wavelength range from 0.4 μm to 2.6 μm in this manner. Comparisons of scanner data in various discrete wavelength bands or channels of the multispectral scanner allow for investigation of the spectral differences between various plant canopy covers.

Kristof and Baumgardner (1970, personal communication) found that a decrease in radiation in the visible and an increase in radiation in the reflective infrared region occurred in comparing multispectral scanner data over crop canopies from April to late June. Disregarding complications of row structure and direction which may produce a "stove pipe effect" (LARS, 1968) in maize canopies, the increase in ground cover could be detected by establishing a ratio of the relative reflectance in the chlorophyll absorption band to the relative reflectance in the near infrared.

Kristof and Baumgardner (1970, personal communication) used the ratio of relative reflectance in the 0.58 to 0.62 μm band to the relative reflectance in the 0.80 to 1.00 μm band to observe increases in ground cover. Considerations of the reflectance properties of green vegetation (Hoffer and Johannsen, 1969; Gates et al., 1965; Knipling, 1970; Myers et al., 1966; Myers, 1970) and that of soil (Baumgardner et al., 1970; Hoffer and Johannsen, 1969; Cipra et al., 1971; bowers and Hanks, 1965; Condit, 1970) would seem to favor a ratio of these two wavelength regions for characterizing canopy density.

Chlorophyll absorbs at 0.65 μm in the visible wavelengths, and it is reasonable to assume that as a crop canopy becomes more dense it would absorb more strongly (and hence, reflect less) in this region. The 0.72 to 1.3 μm wavelength range is the region in which little absorption takes place in green vegetation and in which almost all incident light is transmitted or reflected (Hoffer and Johannsen, 1969). Multiple leaf layer experiments have shown that reflectance in this 0.72 to 1.3 μm wavelength region increases with increasing leaf layers (Myers et al., 1966). Therefore, the reflectance of a crop canopy may be expected to increase in the 0.72 to 1.3 μm wavelength range as canopy density increases. Soil reflectance generally increases slightly in going from the red wavelength region to the near infrared wavelength region, the amount of increase for a particular soil depending mainly on the soil moisture content.

With the increased reflectance in the near infrared and the increased chlorophyll absorption with increasing crop cover, this ratio (chlorophyll absorption band over the near infrared band) would decrease with increasing crop canopy. For a given crop and soil type an estimate of the canopy density could possibly be made from the value of the ratio of the relative reflectance from two channels of a multispectral scanner.

MATERIALS AND METHODS

Plot design and layout were described by Stoner (1972, Multispectral determination of vegetative cover in corn crop canopies, M.S. Thesis, Purdue University, W. Lafayette, Indiana). A set of 12 ground cover plots were laid out near the Purdue University Agronomy Farm's Weather Station on a light colored, Russell silt loam soil. The Pioneer 3369A maize variety was planted in three replications on four planting dates.

Two flight missions by the University of Michigan's airborne multispectral scanner were used in this study. The flight path for both missions was a north-south flight-line directly over the Purdue University Agronomy Farm's Weather Station. Maize plots of various ground covers planted on a Russell silt loam soil were located in the flight path in close proximity to the weather station.

July 12 and July 21, 1971 were the dates for the two scanner overflights. The July 12 flight was at 1401 hours EST while the July 21 flight was at 1305 hours EST. Both overflights were at an altitude of 305 m and both took place on clear, cloud-free days.

The University of Michigan's multispectral scanner collected spectral data in the 0.46 to 2.50 μm reflective wavelength range. Table 1 lists the 11 channels of reflective data collected by the University of Michigan scanner and the corresponding wavelength bands. The aircraft scanner data were recorded in analog form and converted to a digital format for analysis by the LARSYS processing system (LARS, 1968 and 1970). The two flightlines of interest were digitized at a sample rate of 450 samples per scan line of data. This meant that every scan line of analog scanner data was sampled in the digitization process. Each resolution unit represented an area about 1m by 1m on the ground.

The approximate area of the Russell plots was determined from the display of the digitized scanner data on the LARS Digital Video Display Unit. This area was then clustered (Wacker and Landgrebe, 1970) and the exact location of the individual Russell plots was determined from the resulting cluster array map. Each subplot was slightly larger than 4 by 4 ground resolution units or data points. A square block of four data points was selected from the northeast portion of each subplot in order to estimate any shadowing effects from bordering subplots. Statistics on mean scanner data values were then obtained from these data blocks for all of the subplots on both dates of scanner overflights.

The wavelength band configuration of the University of Michigan scanner was changed from that used in previous years. The chlorophyll absorption band for this study fell in the 0.61 to 0.70 μm wavelength range of channel 7. Two near infrared wavelength bands were now available in the region of high reflectance of green vegetation: the 0.72 to 0.92 μm wavelength band of channel 8, and 1.0 to 1.4 μm wavelength band of channel 9.

Ratios of scanner data values were calculated by dividing the scanner data values from channels 8 or 9 by the scanner data values from channel 7 (hereafter referred to as the ratios of channels 8/7 or 9/7). These ratios were then plotted against leaf area index, as measured at the time of the overflights. Stepwise multiple regression analysis was run on the data to see if either of the two ratios of near infrared to red wavelength scanner data response could be related to leaf area index (the ratios were reversed from those mentioned in previous studies for ease in data manipulation).

RESULTS AND DISCUSSION

The ratios of scanner data values in channels 9/7 for the July 12 and July 21 flight dates were plotted against leaf area index (Figure 1). The points seemed to indicate that a rather good relationship existed between the ratio of scanner data in channels 9/7 and LAI. A stepwise multiple regression analysis indicated that 96.8% of the variation about the mean LAI could be explained by the second order regression equation, $\hat{Y} = 1.0751 - 2.8756X + 1.944X^2$, where X is equal to the ratio of scanner data values in channels 9/7. This indicated that ratios of multispectral scanner data may, as hoped for, be related to some ground based measurement of canopy density. The ratios of scanner data values for both dates compared quite well even without any calibration of scanner response between the two dates.

It was expected that the ratios of scanner data values in channels 8/7 should also show a good relationship with LAI. The ratios of scanner data values in channels 8/7 for the July 12 and July 21 flight dates were plotted in Figure 2. It was obvious that two separate relationships existed for the two multispectral scanner flights. Stepwise multiple regression analysis indicated that 98.1% of the variation of LAI could be explained by the second order regression equation, $\hat{Y} = -0.48754 + 1.26899X^2$, where X equals the ratio of scanner data values in channels 8/7 for the July 12 scanner flight. For the July 21 scanner flight a linear relationship was indicated which was able to account for 93.0% of the variation in LAI. The regression equation for July 21 was $\hat{Y} = -2.46111 + 2.18245X$, where X equals the ratio of scanner data values in channels 8/7 for the July 21 scanner flight.

A relationship did seem to exist between the ratio of scanner data values in channels 8/7 and LAI, but the same relationship did not hold between flight dates. Apparently a change had taken place between July 12 and July 21 in the way in which the multispectral scanner was recording data in channel 8. This indicated the need for calibrated scanner data for comparisons over time (between flight dates).

SUMMARY AND CONCLUSIONS

Multispectral scanner data from maize canopies provide more quantitative spectral information on canopy density tan does photography. Ratios of uncalibrated scanner data can be used within a given scanner mission to estimate changes in vegetative cover as measured by leaf area index. The peak reflectance wavelengths for green vegetation (0.72 to 1.3 μm) and the region of strong chlorophyll absorption (0.65 μm) seem to provide the best information on changing ground cover.

Regression equations can be evolved relating leaf area index in maize canopies to the ratios of scanner data values from channels 8 and 9 (0.72 to 0.92 μm and 1.0 to 1.4 μm). These relationships are strong within a given scanner flight, but can only be extended between flight dates when the investigator is certain that there were no changes in scanner system gain settings between flights.

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TABLE 1. THE 11 REFLECTIVE CHANNELS AND CORRESPONDING WAVELENGTH BANDS FOR THE UNIVERSITY OF MICHIGAN MULTISPECTRAL SCANNER.

Channel	Limits of Spectral Bands (μm) Lower	Upper	Wavelength Region
1	0.46	0.49	visible
2	0.48	0.51	visible
3	0.50	0.54	visible
4	0.52	0.57	visible
5	0.54	0.60	visible
6	0.58	0.65	visible
7	0.61	0.70	visible
8	0.72	0.92	near infrared
9	1.00	1.40	near infrared
10	1.50	1.80	near infrared
11	2.00	2.60	near infrared

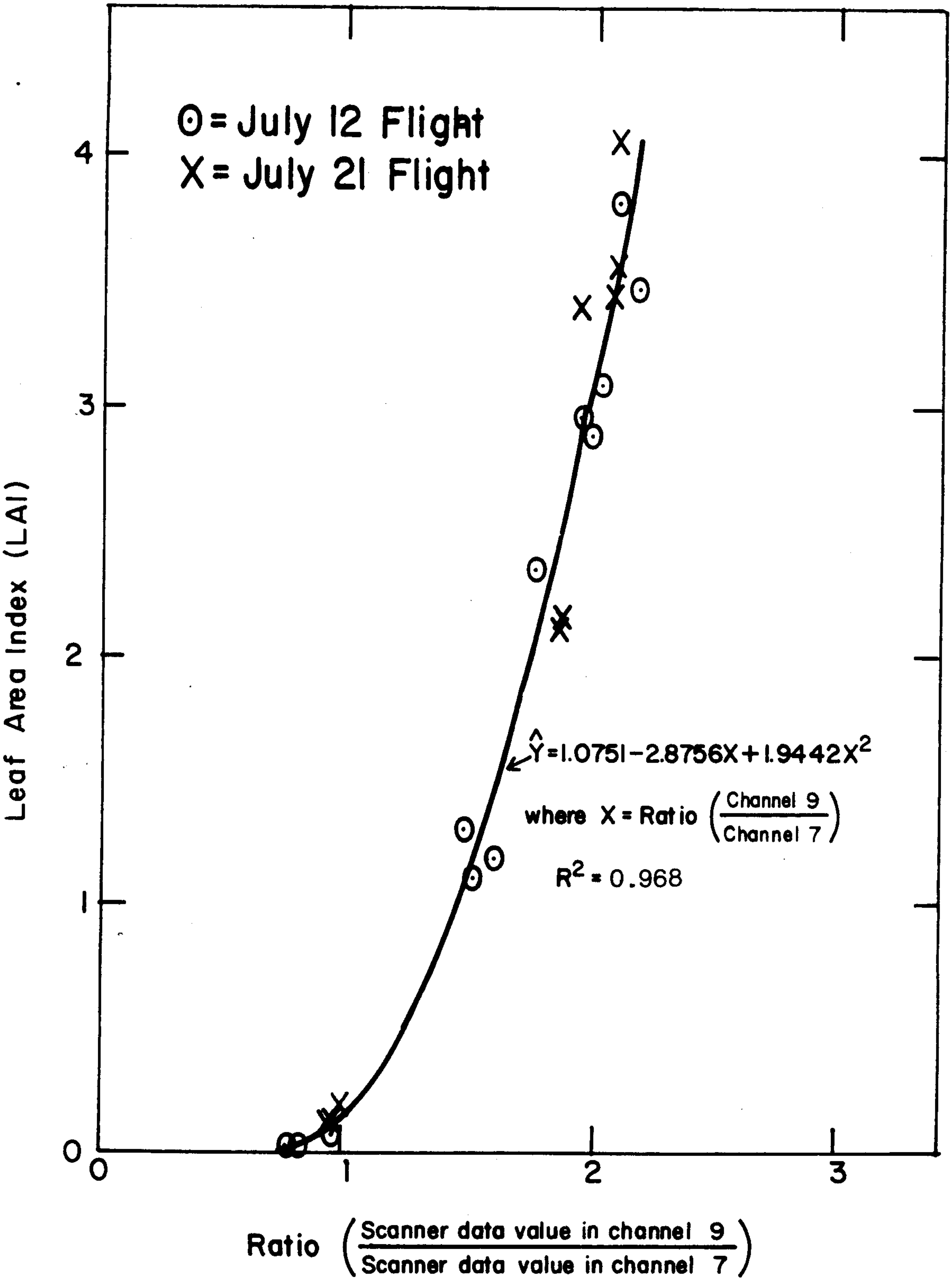

Figure 1. Leaf area index versus the ratio of scanner data values in channels 9/7 for two flight dates.

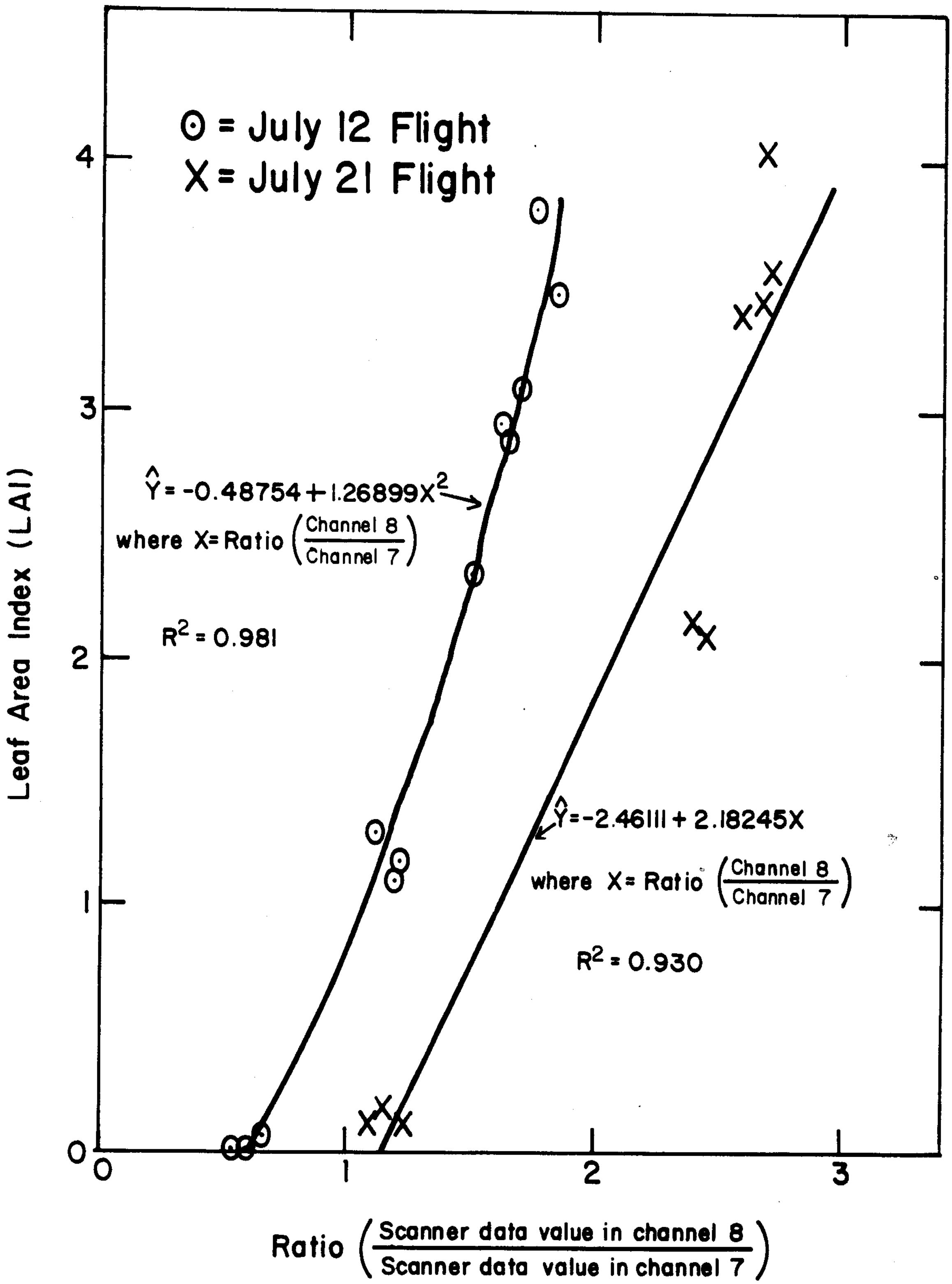

Figure 2. Leaf area index versus the ratio of scanner data values in channels 8/7 for two flight dates.