COTTON CANOPY STRUCTURE, LIGHT ABSORPTION, AND GROWTH IN THE SAN JOAQUIN VALLEY OF CALIFORNIA

S.J. Maas
USDA-ARS
Shafter Research Station
Shafter, CA

Abstract

A study was conducted in 1994 in which field data and remotely sensed data were collected from 63 commercial cotton fields in the southern San Joaquin Valley of California. Statistical analysis indicated that relationships could be determined between growth-related crop factors, including canopy light transmittance and ground cover, and quantities evaluated from Landsat satellite imagery. Correlation was also determined between lint yield and the sum of remotely sensed quantities over a portion of the growing season. These findings suggest that regional crop condition and potential yield might be determined from remotely sensed information.

Introduction

Assessment of the condition of a crop and its yield potential on a regional scale is typically not feasible using ground survey techniques. Satellite and/or aircraft remote sensing can be used to periodically gather crop-related information from the fields in an agricultural region. This information may be useful in assessing the impact of weather conditions on crop progress, the effectiveness of insect management activities, and the potential for crop production within the agricultural region.

Cotton (*Gossypium* spp.) is economically the most important row crop in the southern San Joaquin Valley of California. Studies conducted in the cotton-growing regions of South Texas (Wiegand and Richardson, 1987) and Arizona (Pinter et al., 1994) indicate that statistical relationships can be determined between growth-related crop factors and remotely sensed quantities. I am not aware of comparable studies conducted in the San Joaquin Valley, so it is not known whether similar relationships exist for this region.

The objective of this presentation is to report the results of a study conducted in 1994 involving 63 commercial cotton fields in the southern San Joaquin Valley. Data from this study were analyzed to identify statistical relationships between growth-related crop factors and remotely sensed quantities.

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Materials and Methods

Field Data

Data were collected from 63 commercial cotton fields during the 1994 growing season in the portion of the San Joaquin Valley southwest of Bakersfield, CA. All fields were planted between March 28 and April 15. Fifty-five fields were planted to Acala varieties (primarily 'MAXXA'), while 8 fields were planted to Pima varieties. Fields were planted with either 76-cm (30-inch) or 97-cm (38-inch) row spacings. Plant population density for each field was determined from plant counts following stand establishment.

During the growing season, each field was visited approximately every 2 weeks. During a visit, plant canopy height, ground cover, and light transmittance were measured at 10 randomly selected sites within the field. Light transmittance was measured using a Decagon Sunfleck Ceptometer. Measurements were made during the four-hour period centered on local solar noon. Ground cover was determined as the width of the plant canopy devided by the row spacing. Due to the large size of the fields, measurements were concentrated in one corner of the field. Ten randomly located plants from one of the fields visited on a given day were returned to the laboratory for determination of stage of development, total leaf area, and dry mass. Leaf area index (LAI) was determined by multiplying the total leaf area per plant by the plant population density. Following defoliation, 20 randomly located plants from each field were returned to the laboratory for determination of lint and seed yield. Yield per unit land area was determined by multiplying average yield per plant by the plant population density.

Remotely Sensed Data

Landsat 5 Thematic Mapper (TM) images of the study region were obtained prior to planting (March 13) and on seven dates during the growing season (June 1, June 17, July 3, August 4, August 20, September 5, and September 21). TM bands 1 through 4 of each image were radiometrically corrected using the method described by Price (1987) to determine exoatmospheric reflectance. Measurements of surface reflectance made using a LI-COR portable field spectroradiometer on dates with satellite overpasses were used to correct exoatmospheric reflectance for atmospheric scattering and absorption. Resulting surface reflectance images in TM bands 3 (red waveband, 630-690 nm) and 4 (near-infrared waveband, 760-900 nm) were used to compute normalized difference vegetation index (NDVI) images according to the formula,

$$NDVI = (NIR-RED)/(NIR+RED) \qquad [Eq.1]$$

in which NIR and RED are the reflectances in the red and near-infrared wavebands, respectively. Using a PCI EASI/PACE image analysis system, NDVI data were extracted from the corner of each of the 63 fields in the study where field data had been obtained.

Statistical Analysis

Statistical relationships were sought between remotely sensed and field data using linear least-squares regression. Also, correlations were sought between lint yield and the sums of NDVI and canopy light transmittance over the portion of the growing season in which reproductive growth dominated (approximately June 1 through September 21).

Results and Discussion

Field measurements of canopy light transmittance (T) are plotted versus field measurements of LAI in Figure 1. A linear relationship between LAI and the logarithm of T, forced to pass through the origin, was fit to these data. This relationship is represented by the curve in Figure 1, which has the form,

$$T = \exp(-0.755*LAI) \quad RMSE = 0.110 \quad [Eq.2]$$

RMSE is the root-mean-square error associated with the relationship. Field measurements of T are plotted versus field measurements of ground cover (GC) in Figure 2. A linear relationship,

$$T = 1.471 - 1.873*GC \quad RMSE = 0.316 \quad [Eq.3]$$

was fit to these data. Ideally, the relationship between these two factors should pass through T=1 at GC=0. This phase of the relationship is not indicated in Figure 2, since sufficient observations of plant size were not obtained in this study when the plants were relatively small.

Field measurements of T are plotted versus remotely sensed NDVI observations in Figure 3. Although there is considerable scatter in the data, a general trend of decreasing light transmittance with increasing NDVI is observed. A linear relationship between NDVI and the logarithm of 1-T was fit to these data. This relationship is represented by the curve in Figure 3, which has the form,

$$T = 1 - 0.04*\exp(3.8*NDVI) \quad RMSE = 1.068 \quad [Eq.4]$$

Field measurements of GC are plotted versus remotely sensed NDVI observations in Figure 4. These data were fit with a linear relationship,

$$GC = 1.048*NDVI - 0.139 \quad RMSE = 0.344 \quad [Eq.5]$$

Field estimates of lint yield are plotted versus the sum of canopy light transmittance over the period June 1 (Day 152) through September 21 (Day 264) in Figure 5. A linear regression,

$$Yield = 275 - 1.876*(Sum\ T) \quad g/m^2 \quad [Eq.6]$$

was fit to these data. This regression explained approximately 20 percent of the total variation in observed yield. Part of the scatter in the data shown in Figure 5 is due to the considerable variability among plants in the relatively small samples (20 plants) used to estimate yield for each field. The slope of the relationship indicates that yield increased as the total amount of light absorbed by the plant canopy increased, i.e., as the sum of T decreased.

Field estimates of lint yield are plotted versus the sum of NDVI over the period from Day 152 through Day 264 in Figure 6. A linear regression,

$$Yield = 3.5*(Sum\ NDVI) - 47.1\ g/m^2 \quad [Eq.7]$$

was fit to these data. This regression explained approximately 30 percent of the total variation in the observed data. The slope of this relationship indicates that yield increased as the sum of NDVI increased. Since NDVI is an indicator of plant canopy density, as shown in Figures 3 and 4, this relationship again implies an increase in yield with increasing light absorption. An important distinction between the relationships in Figures 6 and 5 is that Equation 7 represents a remotely sensed indicator of crop yield, which suggests that regional assessment of cotton yield may be feasible through satellite remote sensing. Additional studies conducted under a variety of climatic conditions would be required to determine whether an accurate yield estimation relationship could be developed for operational cotton yield estimation in the San Joaquin Valley.

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Disclaimer

Mention of trade names in this manuscript does not imply endorsement by the United States Department of Agriculture.

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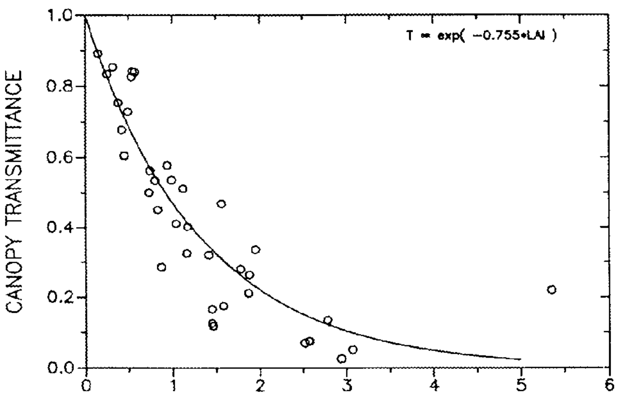

Fig. 1. Field measurements of canopy light transmittance (T) plotted versus measurements of leaf area index (LAI).

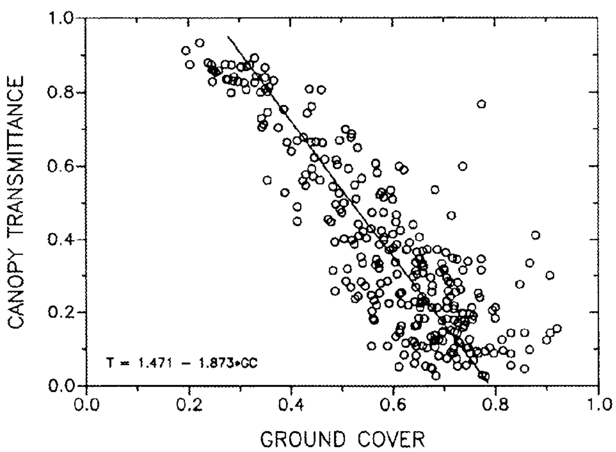

Fig. 2. Field measurements of canopy light transmittance (T) plotted versus measurements of ground cover (GC).

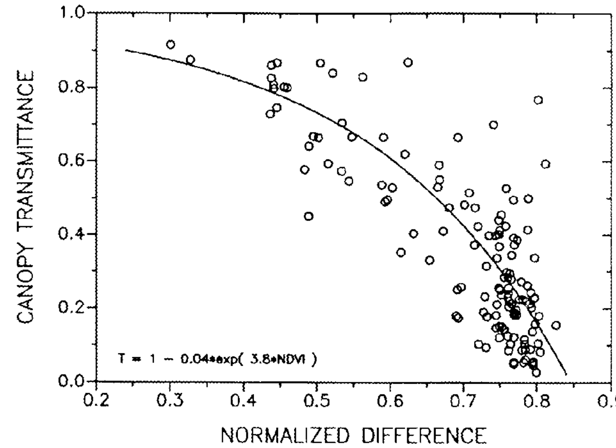

Fig. 3. Field measurements of canopy light transmittance (T) plotted versus remotely sensed NDVI observations.

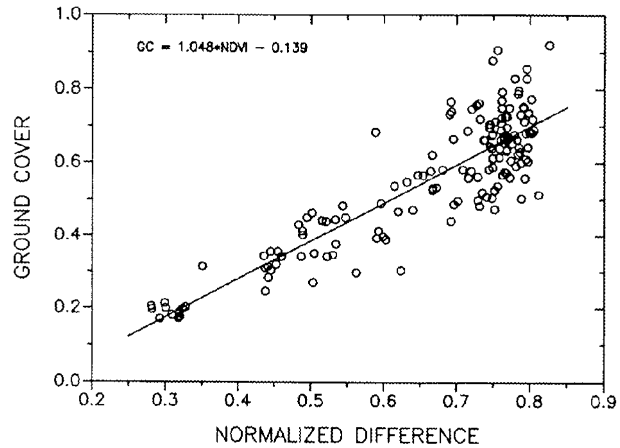

Fig. 4. Field measurements of ground cover (GC) plotted versus remotely sensed NDVI observations.

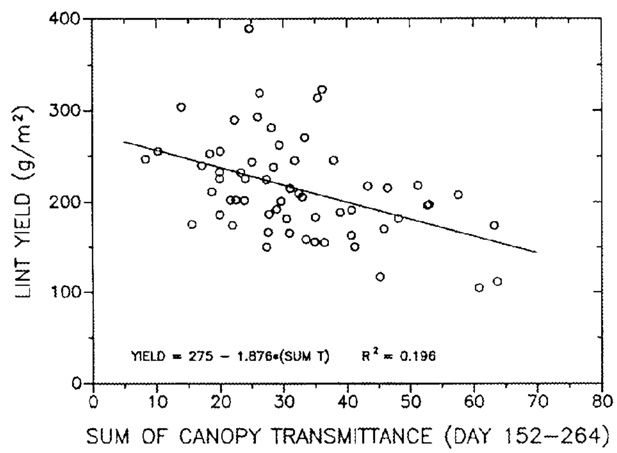

Fig. 5. Field estimates of lint yield plotted versus the sum of canopy light transmittance over the period from Day 152 through Day 264.

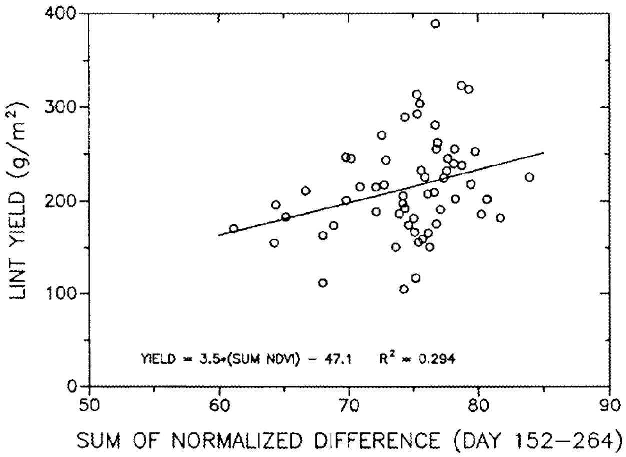

Fig. 6. Field estimates of lint yield plotted versus the sum of NDVI over the period from Day 152 through Day 264.