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Monitoring Corn and Soybean Crop Development by Remote Sensing Techniques

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**MONITORING CORN AND SOYBEAN CROP DEVELOPMENT
BY REMOTE SENSING TECHNIQUES**

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MONITORING CORN AND SOYBEAN CROP DEVELOPMENT

BY REMOTE SENSING TECHNIQUES

ABSTRACT

A system for spectrally monitoring the stages of crop development for corn and soybeans based upon red and photographic infrared spectral radiances is proposed. The red and photographic infrared spectral radiances, highly correlated with the green leaf area index or green leaf biomass, enable nondestructive monitoring of the crop canopy throughout the growing season. Five distinct periods are apparent which are related to crop development for corn and soybeans.

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CONTENTS

	<u>Page</u>
INTRODUCTION.	1
MATERIALS AND METHODS.	2
RESULTS AND DISCUSSION	3
SUMMARY	7
ACKNOWLEDGMENTS	9
REFERENCES.	10

MONITORING CORN AND SOYBEAN CROP DEVELOPMENT BY REMOTE SENSING TECHNIQUES

INTRODUCTION

The application of remotely sensed multispectral imagery for monitoring the condition of agricultural crops and predicting yields has advanced rapidly in recent years. By necessity, much of this effort is coupled with ground-based data on crop development and climatic conditions throughout the growing season. Several numerical schemes for recording stages of crop development have been developed (Hanway, 1963; Hanway and Thompson, 1971). One of the problems, however, in trying to monitor crop condition and predict crop yields has been the inability to collect ground-based crop development data over the large areas generally surveyed in remote sensing projects. Put simply, it is not feasible to collect crop development data to supplement satellite imagery for any large-scale agricultural monitoring project. In extra-country situations, on-site access may be impossible and, in locations like North America or Australia, manpower requirements may be too costly. A possible solution would be to relate remotely sensed data to crop development data, thereby generating a "spectral" crop development value whose inputs would come entirely from remote sensing sources. This paper describes such a method using remotely sensed data collected by a two-channel hand-held radiometer.

MATERIALS AND METHODS

A field of Elinsboro sandy loam soil located on the USDA Beltsville Agricultural Research Center was selected for this study. Four 6 × 6 m plots each of corn and soybeans were planted on April 28 (Julian date 118) and May 20 (Julian date 140) 1977, respectively. Row spacing was 91 cm (23 cm within the row) for the corn and 76 cm (5 cm within the row) for the soybeans. Agronomic data pertaining to crop development, percentage crop cover, and plant height were taken weekly throughout the growing season. Crop development was recorded using numerical scales devised by Hanway (1963) for corn and by Hanway and Thompson (1971) for soybeans. Percentage crop cover (percent of ground covered by the crop canopy) was visually estimated for each plot and plant height was measured in centimeters. In addition to the small plots, a large field (~1 ha) of each crop was planted at approximately the same time. Four 6 × 6 m areas were designated in each field and monitored as a check on the validity of data from the small plots. For both the large fields and small plots soil fertility was optimum and chemical weed controls were used.

Weekly radiance/reflectance measurements were taken on each plot with a two-channel hand-held radiometer (Pearson et al. 1976) beginning May 31 (Julian date 151) for the corn and June 21 (Julian date 172) for the soybeans. The two channels (spectral bands) used were .650-.700 μ m and .775-.825 μ m. These wave lengths have been shown to be of excellent utility for monitoring green vegetation or green leaf biomass (Pearson and Miller, 1972; Gausman et al.,

1973; Tucker, 1978). The .650-.700 μ m band, situated in the red region of the spectrum, is inversely related to the chlorophyll content. The .775-.825 μ m band, situated in the photographic infrared region, is directly related to the green leaf area index or green leaf biomass. A vegetation index (VI) was calculated from the radiance readings as follows after Rouse et al. (1973):

$$VI = \frac{(IR - Red)}{(IR + Red)}$$

Each week, 16 red and ir measurements were made for each soybean plot; 24 were made for each corn plot. Data were collected from a 1.5-m ladder for corn plots and from the ground for the soybean plots. The hand-held radiometer was held ~3.5 m and ~1.5 m above the ground surface for the corn and soybean canopies, respectively. Data from each experimental plot were averaged and the mean values used thereafter in the analysis (Tucker et al., 1978).

Although an attempt was made to sample the experimental plots every 7 days on sunny days between the hours of 1100 and 1500 EDT, weather conditions often precluded the 7-day sampling procedure. Actual measurements were usually made at 6- to 8-day intervals, with the minimum interval being 4 days and the maximum being 12 days.

RESULTS AND DISCUSSION

Agronomic and spectral measurements were similar for the four corn plots as were measurements for the four soybean plots (Tucker et al., 1978a). Figure 1 illustrates the relationship between the VI, percentage crop cover, and plant height

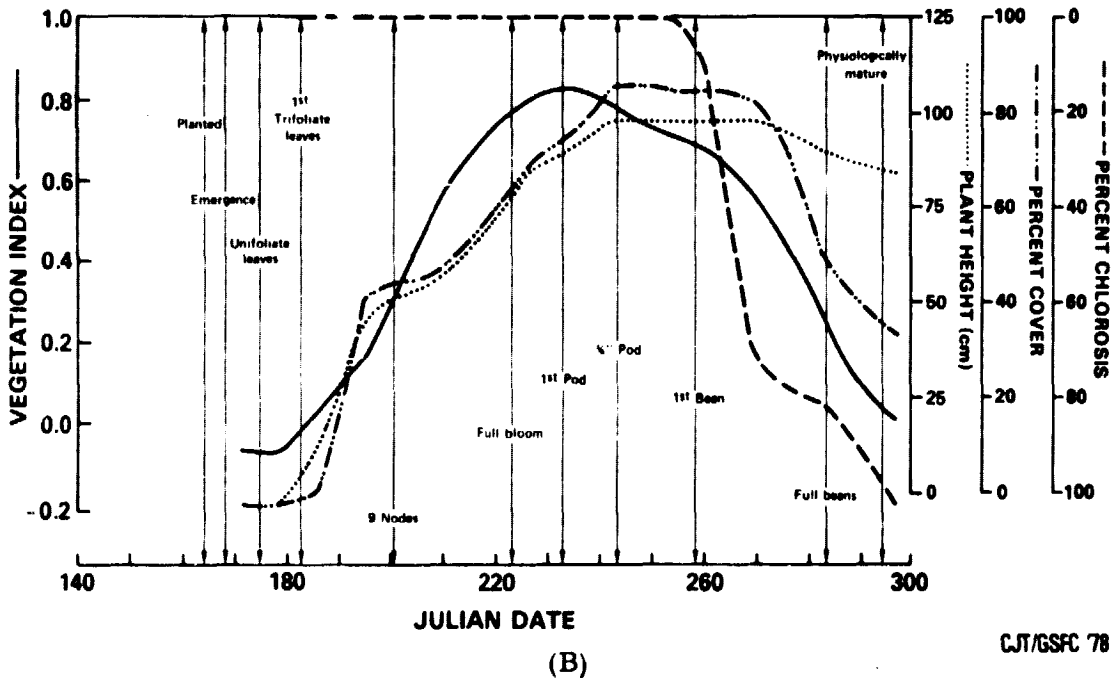
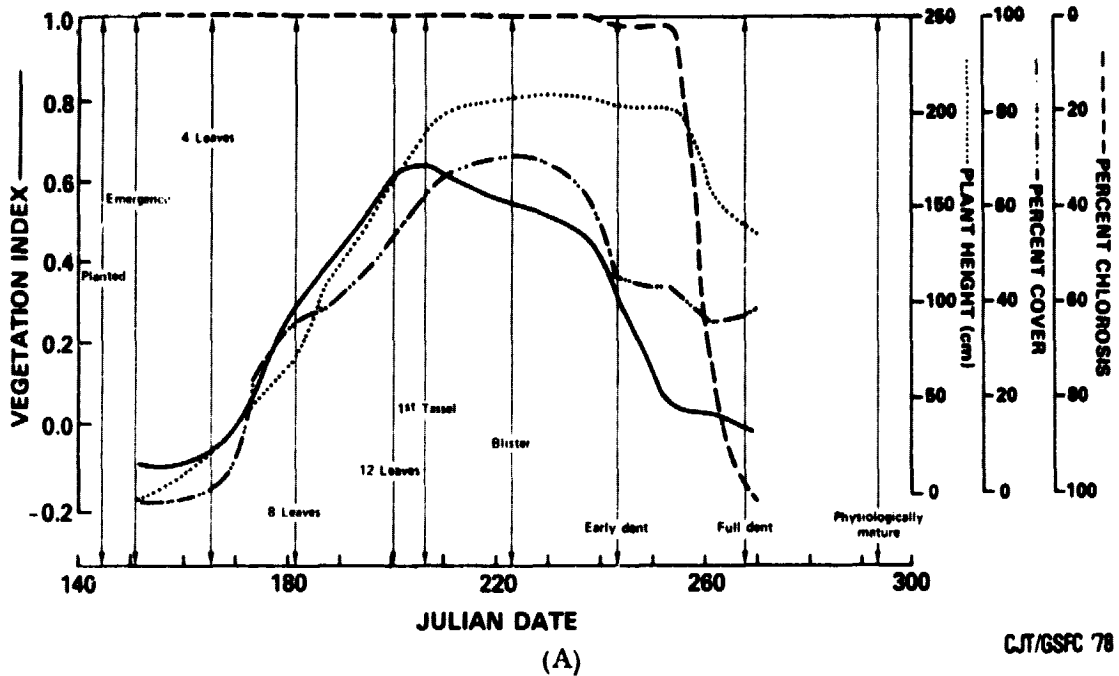


Figure 1. The VI $[(ir - red)/(ir + red)]$, plant height estimated crop cover, and estimated chlorosis are plotted against Julian date for (A) corn and (B) soybeans. In addition, agronomic data pertaining to stage of growth is also noted with respect to Julian date. Each plot is the average of two replicates having the same agronomic treatment(s).

during the growing season for representative plots of each crop. Both percentage plant cover and plant height were closely associated with VI (Tucker et al., 1978a).

Data from the large fields were similar to those for the small plots.

Five stages of spectral crop development (SCD) were observed for the corn and soybean plots (Figures 2a and 2b);

Stage 1. For both crops, the VI for the bare soil before crop emergence and after emergence up to 10-20% cover was negative.

Stage 2. The rapid increase in vegetative crop cover which occurred for both corn and soybeans prior to bloom was indicated by a rapid increase in VI.

Stage 3. Once full vegetative crop cover was achieved, a plateau in the VI was detected. SCD Stage 3 continued during crop bloom and until crop chlorosis was detected.

Stage 4. During the period of crop maturation and dry-down, the VI declined gradually. Leaves became chlorotic and were often lost from the plants.

Stage 5. SCD Stage 5 was detected when the soybeans had lost all leaves and the corn had lost all color, i.e., when the crops were mature and ready for harvest. The VI was once again similar to that measured at crop emergence.

The two principal factors which influence or control the VI are the chlorophyll density and the green leaf biomass. Conditions which affect either chlorophyll density or green leaf biomass are expressed in the VI values. For example, stress conditions such as drought would affect the VI by limiting plant growth and the plateau point would be reached at a later date or a lower plateau would

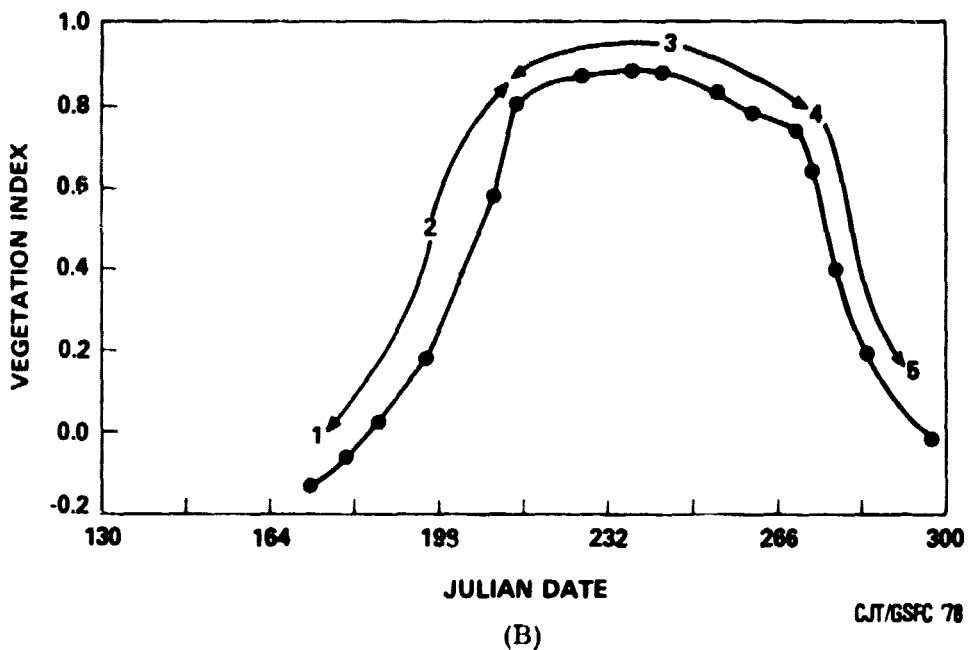
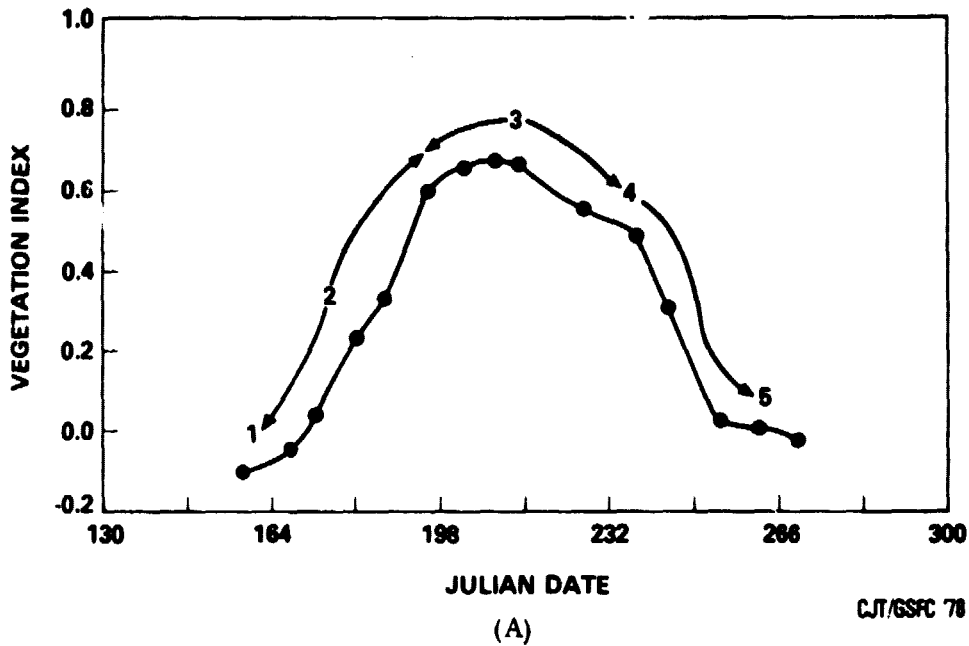


Figure 2. Spectral Crop Development stages for (A) corn and (B) soybeans. Five stages are apparent: 1. Emergence up to 10-20% vegetation cover; 2. Rapid foliar growth and development; 3. Full vegetative cover; 4. Onset of senescence, crop maturation, and dry down; 5. Crop maturity, ready for harvest. The averaged VI is plotted against Julian date for two replicates for each crop.

be attained. Or, if drought conditions occurred after the plateau had been reached, the plant canopy would respond by wilting and a reduction in the VI would occur.

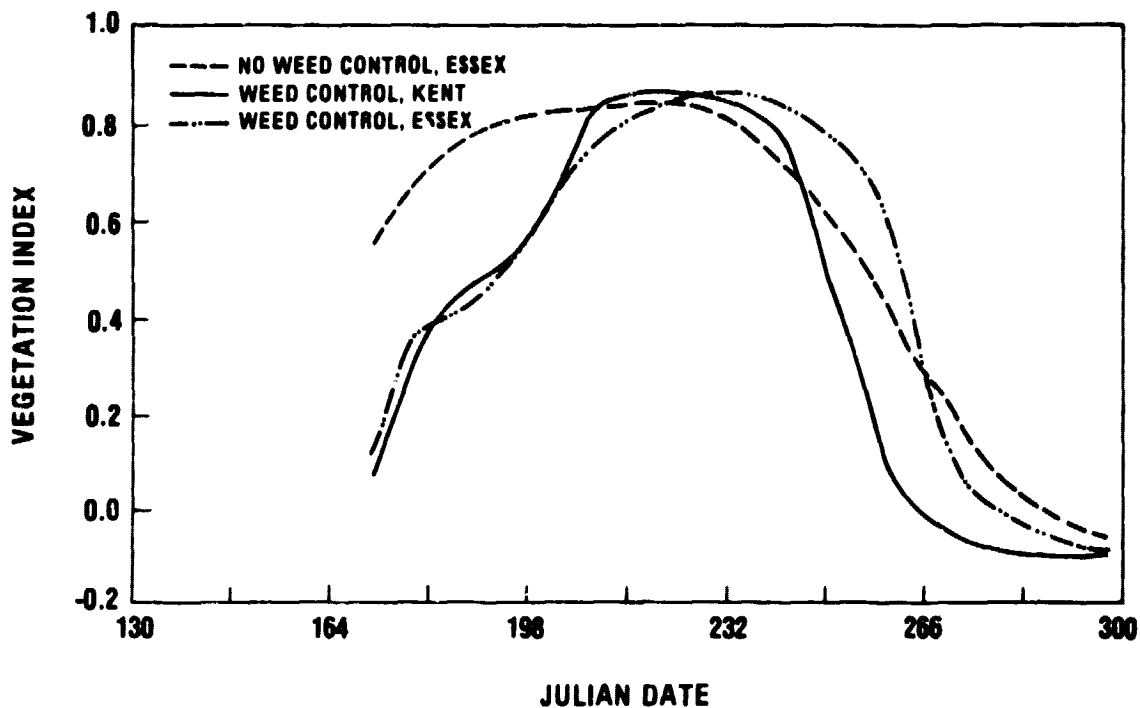
Chlorosis, a decrease in chlorophyll density which is brought about by unfavorable environmental factors, would also be expressed in lower VI values. Soil fertility, particularly nitrogen, would affect the accumulation and density of green biomass and thus would be expressed in the VI. High fertility would result in higher values for the VI while low fertility would result in lower values.

Weeds pose a confounding problem for the VI as the VI is sensitive to green biomass whether it is weeds, crop, or weeds and crop. However, the sensitivity to weeds by the VI could possibly be exploited to detect the presence of substantial patches of weeds. If unexpectedly high values for the VI were found earlier in the growing period, this could indicate the presence of some other type(s) of green leaf biomass (Figure 3).

The relationship between the VI and crop development observed in our study indicates the utility for an assessment of crop condition through spectral measurements. Attaining and sustaining full vegetative cover stage is an important factor in conditioning the final yield of any crop. The spectral assessment of the stages of crop development is an important step toward making yield predictions by remote sensing.

SUMMARY

1. A system for monitoring the stages of crop development based solely upon red and photographic infrared spectral measurements is proposed for corn and soybeans.



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Figure 3. Comparison between the VI's for three different agronomic treatments for soybeans. Note how the presence of weeds in the "no weed control" plot resulted in higher VI values than the other soybean treatments with weed control earlier in the growing season.

2. Five distinct and spectrally measurable stages are apparent for these two crops:

- A. Emergence up to 10-20% vegetative cover**
- B. Rapid foliar growth and development**
- C. Full vegetative cover**
- D. Onset of senescence, crop maturation, and dry down**
- E. Crop maturity, ready for harvest.**

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