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EVALUATION OF REMOTE SENSING CAPABILITIES IN WEED DETECTION AND MAPPING IN COTTON

Dorgelis Villarroel, Javed Iqbal, Alex Thomasson, and Scott D. Stewart
Mississippi Agricultural and Forestry Experiment Station
Mississippi State University
Mississippi State, MS

Abstract

Field studies were conducted in 2002 at Long View Farm located in east-central Mississippi. Two cotton fields, Field-104 and Shop Field, were selected for the remote sensing of the biophysical properties of the cotton crop. At each field plots were laid out using previous crop normalized difference vegetation index (NDVI) into low, medium and high categories. The objectives of the study were to determine the potential of spectral analysis of multispectral images and field spectroradiometer data for discriminating morningglory and grasses from cotton canopy. Multispectral images were used to derive NDVI temporal pattern analysis to discriminate weeds from cotton canopy and feature extraction technique were used to identify and map morningglory on field basis. Images acquired on July 18, and August 28 show lower NDVI values in the field where weeds were intermixed with cotton plants compared to weed-free cotton canopy. Near infrared band (850 nm) of the multispectral imagery and spectroradiometer ~ 750 – 1000 nm wavelength region showed promising results for discriminating between weed-free cotton canopy and cotton canopy with morningglory. Spectral extraction process identified and mapped < 50 % of the weeds present in the study area.

Introduction

The potential for using plant reflectance spectra in precision agriculture has been the focus of many researchers. Applications investigated include, nutrient management, monitoring yield quantity and quality, and the detection of insects and weeds for selective pesticide and herbicide applications. The reflectance spectra of most green leaves are remarkably alike due to similarities in chemical composition and leaf structure. Plant pigments such as, chlorophylls and carotenoids, have major effects on the reflectance properties of green leaves in the visible wavelengths; whereas the reflectance properties in the near-infrared (NIR) are due primarily to differences in leaf structure (Gates et al., 1965). Absorption by chlorophylls *a* and *b* dominate the visible wavelengths for most green plants with features occurring at 430 and 670 nm for chlorophylls *a* and at 460 and 650 nm for chlorophyll *b*. However, these properties are not entirely responsible for the reflectance of vegetation canopies in remotely sensed imagery because a vegetation canopy is composed of a mosaic of leaves, flowers, stems, and shadows against a soil background. So the reflectance properties derived from remote sensing of vegetation are primarily due to reflectance at the canopy level, however, the chemical composition of plants can influence these values.

To differentiate and map different vegetations and insect damage, many different types of remote sensing data and image processing techniques has been used in the past. Satellite remote sensing is limited as a tool for monitoring detailed within-field variation because of insufficient resolution. However, aerial imagery techniques have been used for many years for monitoring the spread of disease across specific crops. Two approaches have typically been used for monitoring weed and insect damage in cultivated crops. The first approach is to detect geometric differences between the crop and weeds, such as leaf shape or plant structure. The second approach is based on differences in spectral reflectance. Since, most of the cultivated crops have a different growth and development pattern than the weeds, another approach could be by examining the temporal patterns of vegetation indices throughout the growing season. There may also be a difference in location of the crop compared to weeds.

Insect's pressure was negligible in the study area due to farmer aggressive insecticide application throughout the growing season. Therefore, the overall objectives of this study was limited to only identification and mapping of different types of weeds using remotely sensed multispectral imagery and field spectroradiometer data.

Materials and Methods

Field studies were conducted in 2002 at Long View Farm located in east-central Mississippi. Two cotton fields, Field-104 and Shop Field, were selected for the remote sensing of the biophysical properties of the cotton crop. At each field plots were laid out using previous crop normalized difference vegetation index (NDVI) into low, medium and high categories. A comprehensive bi-weekly data collection process began at the beginning of each growing season, which include the plant mapping, percent defoliation, stand density, insect damage, disease incidence, weed severity rating, collection of soil and plant tissue samples for fertility and nematode analysis, and canopy GER reflectance. Multispectral imagery data was acquired throughout the growing season. These data were collected by GeoVantage using a 8-bit real time camera system at a spatial ground resolution of 0.5-m. Spectral resolution width was 80-nm except near-infrared band which was 100-nm and the four bands were centered at 450 nm (band 1=Blue), 550 nm (band 2=green), 650 nm (band 3= red), and 850 nm (band 4 =NIR).

At the end of each growing season cotton yield monitor data was collected. A widely used vegetation index is the NDVI. NDVI is an indicator of crop biomass production and canopy vigor:

$$NDVI = \left(\frac{NIR_{850} - R_{650}}{NIR_{850} + R_{650}} \right)$$

To identify particular weed specie, the field was surveyed and high concentrated weed patches locations were marked with a GPS system. Two major types of weeds were found in the study area morningglory (*Ipomea lacunosa*) and grass specie.
To map weeds in the field based on differences in spectral reflectance between cotton crop and morniningglory and the grass specie, two approaches were used:

1. NDVI maps were generated for July 18 and August 28 imagery to discriminate temporal pattern of crop and weed.
2. A new technique of feature extraction was used in a geographic information system (GIS) environment in which a user create a feature model by hand-digitizing locations of the features on multispectral image, and the software learn based on the user's model and return features in a shape file that closely resemble the features provided.

The above mentioned simplified approaches were used to discriminate and map morningglory and grass in the cotton fields.

Results and discussions

Figure 1 shows marked (filled red triangle) locations of the morningglory and grass weeds on top of the multispectral image taken on July 18, 02. The high concentrated patches of weeds are distinctive as green color as compared to the reddish cotton canopy background. To show the difference in growth pattern between weeds and cotton canopy NDVI maps were derived from July 18 and August 28 multispectral imagery using those two marked areas in the field. The digital number (DN) based NDVI were ranged between 0.09 to 0.27 for July 18 and 0.04 to 0.24 for August 28 multispectral images. The lowest NDVI values were recorded for areas with dense dominant grass stand patch whereas the surrounding healthy cotton canopy has a distinctive light green to dark green color. Comparing the two NDVI maps one can notice the distinctive pattern of growth between weeds and cotton crop and this behavior can be used as tool for separating the species.

To show the effectiveness of multispectral image spectra, pixels DN values were extracted which include: marked weed (grass and morningglory) areas (Fig. 1) of the field, healthy cotton canopy, bare soil, and water. The blue (450 nm), green (550 nm), and red (650 nm) were not effective in discriminating between weed-free cotton canopy and cotton canopy with weeds either morningglory or stand of grass, while as expected, the same wavelengths showed a distinctive pattern over soil and water. The DN values derived from the NIR band (850 nm) over cotton canopy clearly differed from morningglory, grass, bare soil and water (Fig. 3). The NIR DN values were distinctively higher for cotton canopy without any weeds than over morningglory mixed with cotton canopy, or bare soil and water. This could be due to the fact the morningglory intermixed with cotton canopy have much less reflectance in the chlorophylls-absorption region (550- 650 nm) and much higher reflectance in the NIR region, however, the weeds reduced the NIR reflectance.

Figure 4 shows the comparison of average field spectroradiometry spectra of cotton canopy, cotton canopy with *Alternaria* disease symptoms + morningglory, soil, and cotton canopy infested with heavy morningglory. Cotton canopy infested with either weeds (morningglory and / or grass) or *Alternaria* disease clearly differed from cotton canopy without weeds, which was easily differentiated primarily based on percentage reflectance values between 750 nm – 1000 nm wavelength region. The highest percentage reflectance spectra was in the order of cotton canopy without any weeds, cotton canopy with medium intensity (rated 3 on the scale from 0 – 5, whereas 5 is considered as the highest intensity of morningglory intermixed with cotton canopy) of weeds + *Alternaria* disease symptoms on cotton leaves, bare soil, and followed by cotton canopy intermixed with heavy intensity (rated 5) of morningglory. Alteraria leaf spot caused by *alternaria macrospora,* a fungus that infect the cotton leaves, brackets and bolls. Cotton is fairly tolerant in the dry weather condition, but under high humidity or rainfall, which was the case during 2002 growing season, spores are produced that are windblown or splashed on cotton plants. Red lesions appeared where spores have germinated and grown into host tissue (photo 1). Figure 4 clearly illustrated the effects of severe symptoms of *Alternaria* disease symptoms, which reduces the spectral reflectance of cotton in the NIR region, compared to healthy crop. The above results clearly indicates that morningglory and *Alternaria* disease symptoms on cotton leaves reduced the percentage reflectance in the NIR band significantly and this behavior of the weeds during the month of July can be used as a tool to differentiate different vegetation species in the field.

To achieve the second objective of this study, the feature extraction process was used in the GIS environment. A feature model was created by hand-digitizing locations of the morningglory and grass on multispectral image, and the software learned based on the model input and return features in a shape file that closely resemble the features provided. This methodology was applied on the July 18 multispectral imagery (Fig. 5). The key point to successfully extract the pixels location where weeds are intermixed with cotton canopy is to locate and train the software. The resultant map shows the location of morningglory and grass in the 104-Field and shop-Field. By this methodology only < 50% of the weeds were mapped, due to difficulty in locating a pure pixel location of morningglory in the image.

References

Gates, D.M., H.J. Keegan, J.C. Schleter, V.R. Weidner. 1965. Spectral properties of plants. Applied Optics. 4:11-20.

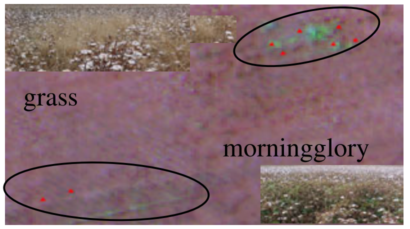

Figure 1. Multispectral Imagery taken on July 18 showing marked area of morningglory and grass.

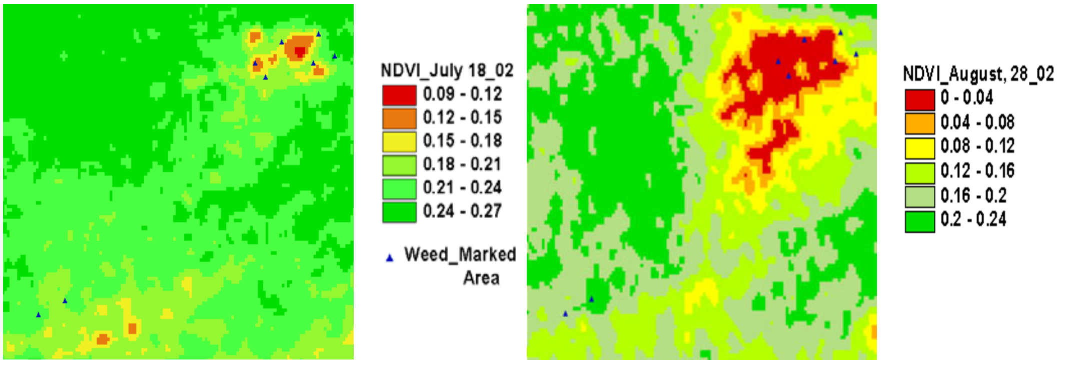

Figure 2. NDVI based discrimination between cotton canopy, morningglory + cotton canopy, and grass.

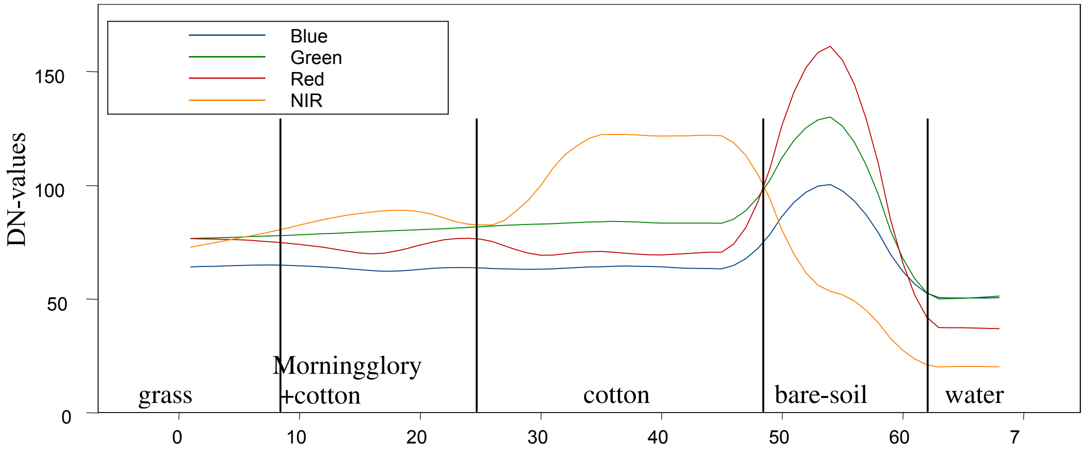

Figure 3. Comparison of the digital numbers of blue (450 nm), green (550 nm), red (650) and NIR (850) of grass, morningglory + cotton canopy , cotton canopy, bare soil, and water. Multispectral Image was taken on July 18 over marked area of morningglory and grass in fig. 2.

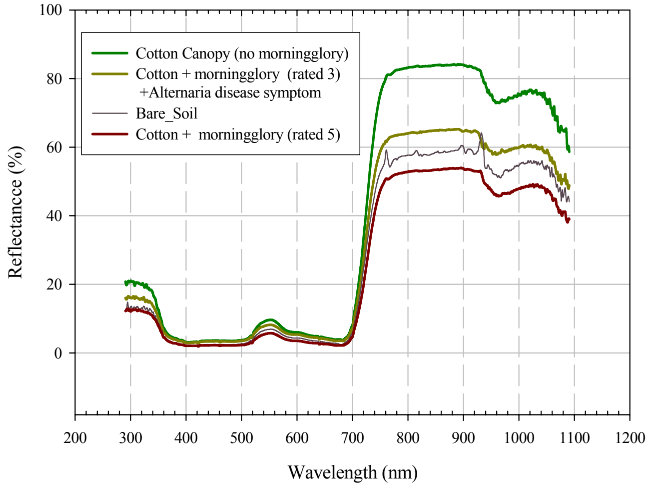

Photo 1. Red lesions on cotton plant leaves, symptoms of Alteraria disease

Figure 4. Comparison of average field spectroradiometer spectra of cotton canopy, cotton canopy with *Alternaria* disease symptoms + morningglory, soil, and cotton canopy infested with heavy morningglory.

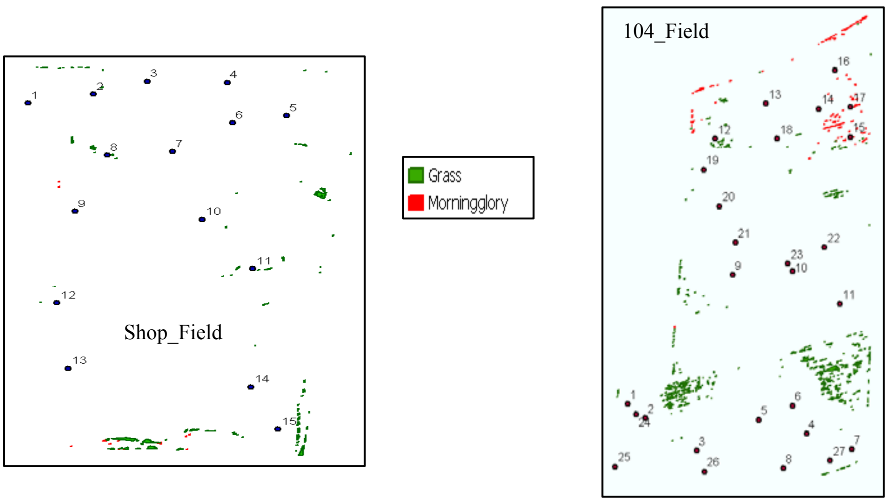

Figure 5. Feature based discrimination of morningglory and grass from cotton canopy using multispectral image taken on July 18, 02.