ASSESSING SPIDER MITE DAMAGE IN COTTON USING MULTISPECTRAL REMOTE SENSING

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Abstract

Spider mites (*Tetranychus* spp.) are a serious pest in California cotton. Field scouting followed by pesticide application to an entire field is the usual method for detection and control of these pests. In this study, the Shafter Airborne Multispectral Remote Sensing System (SAMRSS) was flown over cotton fields to determine if spider mites could be detected early enough in the season for farmers to take corrective action. Images were acquired on 29 dates during the 1999 growing season in the green (550 nm), red (660 nm), and near infrared (850 nm) wavelengths. Images taken of these fields revealed little information about the status of mites in the fields. However, an image processing protocol was developed from which mite damaged regions could be identified in post-processed image maps shortly after they were detected on the ground. Thus, remote sensing can be an important tool that through image processing could provide information in the form of maps to field scouts to assist in locating spider mite infestations. Additionally, pesticide applications could be reduced by applying only to regions identified as being infested by mites.

Introduction

Spider mites (*Tetranychus* spp.) are a serious pest in cotton in California. They feed on plants causing wounds such as leaf puckering and discoloration in early stages and leaf drop later (Anonymous, 1996). The strawberry spider mite, *Tetranychus turkestani*, is the most serious of the mite pests on cotton in the San Joaquin Valley. The reddish discoloration that appears on the upper surface of the leaves and the patterns they cause in the canopy may be detectable through remote sensing.

Remote sensing has been shown to be an effective tool in identification of important agronomic pests, including disease (Summy, et al., 1997), weeds (Brown, et al., 1994), and mites (Penuelas, et al., 1995). Based on data from the USDA-ARS, Shafter, CA research plots during the 1998 season it was shown that the color shift and field patterns caused by mites can be detected through remote sensing (Fitzgerald et al., 1999a, b). A second year of data collection and analysis was undertaken to show that mite damage could be identified early enough in the season for the farmer to take corrective action.

Typically, mite control is achieved by field scouting at critical times during the growing season by sampling leaves and counting mites. If a population threshold is reached, the entire field is treated with pesticides. Remote sensing offers the potential to identify regions within a field indicative of early spider mite infestations. A map could be provided to a field scout or farmer which could help focus scouting efforts. Pesticide applications could be reduced by applying only to regions identified as being infested by mites. Reduced pesticide application could lower costs to the farmer and benefit the environment by reducing the quantity of pesticide applied.

Materials and Methods

Image Acquisition

The Shafter Airborne Multispectral Remote Sensing System (SAMRSS) was flown over cotton research plots at the USDA-ARS station in Shafter, CA on 29 dates between March and September, 1999. SAMRSS is composed of 3 digital cameras with narrow band filters centered on 550 nm (green), 660 nm (red), and 850 nm (near infrared) wavelengths. Images were acquired at 1525 m (5000 ft) above ground surface resulting in a spatial resolution of 0.65 m (2.1 ft). Flights occurred within 15 minutes of solar noon to reduce shadows.

Ground Data Collection

Field scouting for mites was performed regularly during the season. Maps produced were used to identify regions of early infestations and select training areas for supervised classification of the images. A portion of an adjacent field was left fallow to provide a bare soil reflectance reference. Three calibration panels (7%, 30%, 95% reflectance) were used to convert digital numbers to percent reflectance as described previously (Fitzgerald et al., 1999b).

Image Analysis

Images were analyzed using ENVI software from Research Systems, Inc., Boulder CO. All images were registered to each other, subset, and masked to show the cotton fields of interest. A minimum noise fraction (MNF) algorithm was run to segregate the noise and decorrelate the images (Anonymous, 1997). This transformation is essentially two cascading Principal Components analyses (PC), the first rescales the noise and the second is a standard PC analysis on the noise-whitened data. This allows good separation of the data for classification algorithms. To classify the PC images, a supervised classification routine, spectral angle mapper (SAM), was performed to divide the images into “mite damaged”, healthy, and soil classes. The SAM compares the spectra from known regions selected by the operator (training

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sets) with all other pixels in the input images and groups the pixels based on similarity in terms of the spectral angle between them in data space. It is insensitive to illumination so problems associated with bidirectional reflectance should be minimized. The SC was followed by development of change maps between important dates based on the equation:

eg. 1. $C_1/C_2 * 6$

This was applied to date pairs of SC images to create change maps where C_1 = classified map on an early date and C_2 = classified map on a later date. When the classified image from date 1 is divided by date 2 (both have values ranging from 1 to 3 - "mite damaged", healthy, soil) and multiplied by 6 the resulting integer values are unique identifiers of each new class. For example, change in the canopy over time from healthy to mite damaged can be quantified.

Results and Discussion

The training sets selected for the supervised classification (SAM) represented known (ground referenced) areas of "mite damage", healthy canopy, and soil. Using the SAM algorithm, the computer located other regions in the images that were spectrally similar to the training sets (Fig.1). The classified images from each date were visually inspected for agreement with known ground conditions. Since the classification routine was forced to classify all pixels in the images some regions shown include mixtures of features. Regions within the white (soil) class in Fig. 1 are those that include pixels ranging from bare soil to having some plants but whose spectral signatures more closely matched the soil training set. Similarly, the dark gray color includes those pixels whose spectral signatures most closely resembled mite infested regions but that had spectral mixes with other characteristics. Based on ground data, these characteristics were: leaf color, plant architecture (smaller, more open), and soil. This resulted in classification maps with patterns that remained fairly constant between dates and were difficult to interpret, especially early in the season (Figs. 1a, b).

Since mite infestation is a dynamic process, detecting change by quantifying differences between classified images from two dates might identify regions of early mite infestation. Dates were chosen to overlap the period when mites were first detected in the fields (between July 16 and 21) to determine how soon afterwards they could be detected in the images. Equation 1 was applied to date pairs of SC images to create change maps. Several intervals were tested and it was found that 3 to 4 days was sufficient to notice changes in the images. Examples of change maps derived for periods during early and late mite infestations are shown in Figs 2a and 2c. This removed the fixed patterns in the SC images that made them difficult to interpret (Fig. 1). Thus, maps were produced showing changes from one class to another (Fig. 2a, c). The only changes considered here are those for "healthy to mite" and "healthy to soil" which are taken together and display as dark gray in Figs. 2a and 2c. (A color version can be found at: http://pwa.ars.usda.gov/uscrs). These indicate changes in the healthy canopy to conditions indicative of mite infestations. The 'healthy to soil" class likely shows a reduction in canopy vigor probably due to more soil becoming visible in the pixel and thus, a shift to a new class indicative of reduced vigor.

The dark gray pixels in the change maps (Figs. 2a, c) are caused by either changes from healthy to less healthy canopy conditions or by problems in registration or misclassification between images. Although some individual pixels may be misclassified, when numerous pixels form natural groupings (as shown in Fig. 2a), they indicate regions that a field scout or farmer should investigate. Also evident in Figure 2 is that the NIR images show very little indication of mite damage. Some patterns are visible in the August 12 image and it is noticeably darker than the July 16 image but by then damage to the crop was severe and it was too late to be remedied. Computer enhancement early in the season and shortly after mites were detected on the ground successfully identified regions that later became heavily infested with mites.

After July 16, when mites were first detected, they entered field 41 from the SW edge (Figs. 1c, 2c). This progression was tracked by collecting extensive ground data and was evident in the change maps. The regions of known mite infestations closely resemble the patterns in the change maps (Figs. 2a, c). Although the maps show "mite damaged" regions in field 42 earlier in the season (Fig. 2a), these did not develop into infestations (Fig. 2c). Thus, information from remote sensing can be very useful as a tool to supplement knowledge of ground-based events but should not be used exclusively to make management decisions.

Conclusions

- Multispectral remote sensing can detect mite infested regions shortly after they are detected on the ground
- Multitemporal images can detect changes in dynamic processes in cotton fields, such as mite infestations
- Remote sensing can be an important tool that through image processing can provide maps to field scouts to assist in locating spider mite infestations
- Pesticide amounts might be reduced if precision techniques for application are utilized in mite infested regions identified by remote sensing

Disclaimer and Acknowledgments

Mention of specific suppliers of remote sensing software in this manuscript is for informative purposes only and does not imply endorsement by the United States Department of Agriculture.

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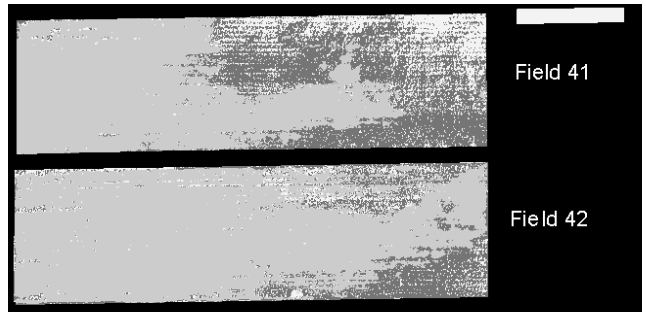
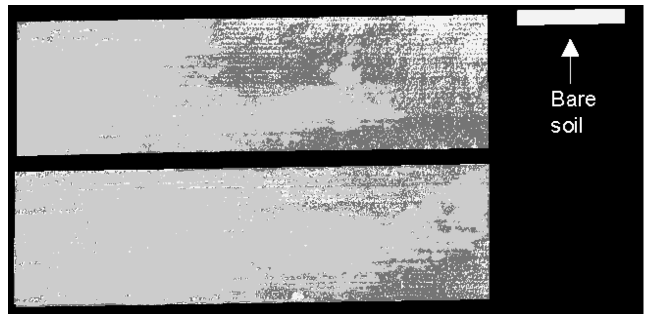
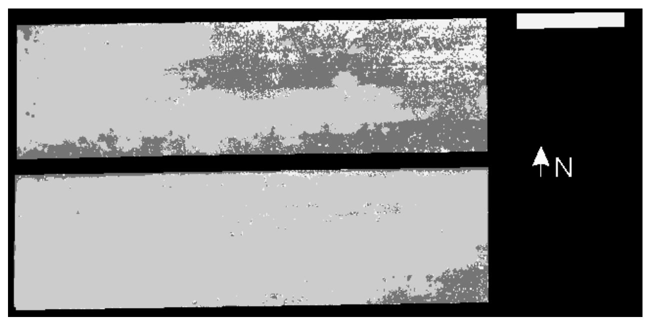


a. July 16, 1999

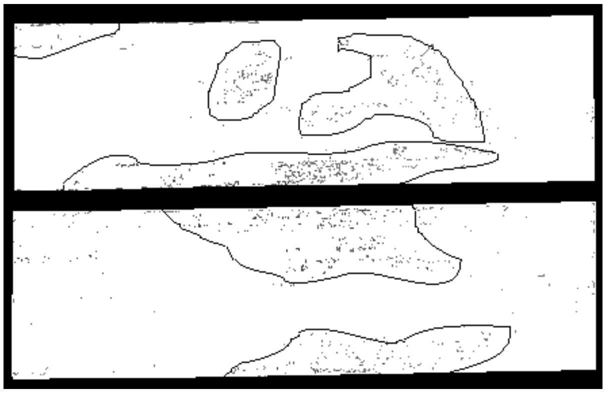


b. July 20, 1999

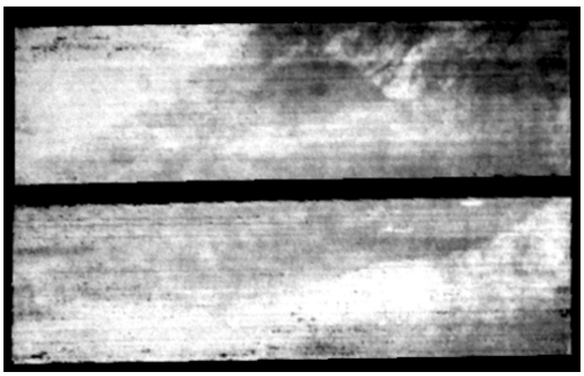


c. August 12, 1999

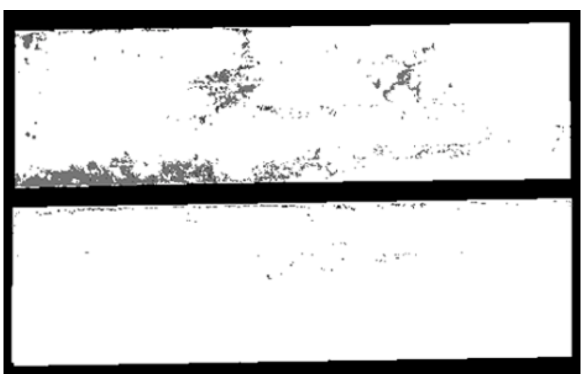
Figure 1. Supervised classification of images. Dark gray = "mite damage", light gray = healthy canopy, white = soil. Early season classified image maps (a, b) and late season map (c). Note the dark gray areas along the southern edge of Field 41 and points or "hot spots" along the west side of Field 41. They indicate severe mite damage late in the season in figure c.



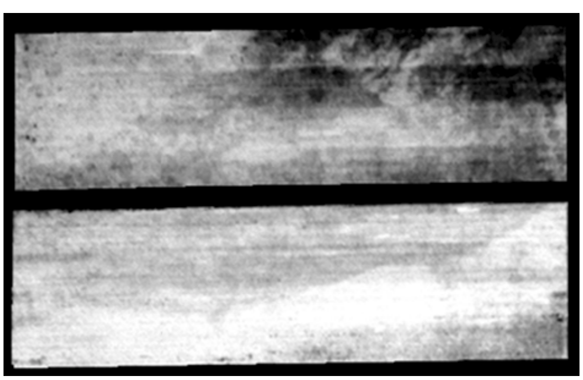
a. July 16 and July 20



b. July 16, 1999



c. July 20 and August 12



d. August 12

Figure 2. Change maps derived from SC images in Fig. 1 (a, c). NIR images (b, d). Dark gray pixels in a and c = “healthy to mite” and “healthy to soil” class changes. Early season change map (a) coincides with first ground detection of mites. Late season map (c) shows fields after mites caused severe damage in Field 41. Regions of early mite detection are outlined in a.