APPLICATION OF LOW ALTITUDE AVIRIS IMAGERY OF AGRICULTURAL FIELDS IN THE SAN JOAQUIN VALLEY, CA, TO PRECISION FARMING.

Nahum Gat, Hector Erives
Opto-Knowledge Systems, Inc. (OKSI), Torrance, CA

Stephan J. Maas, Glenn J. Fitzgerald
U.S. Department of Agriculture (USDA) Agriculture Research Station (ARS), Shafter, CA

1. Introduction

Precision agriculture is a method of managing crop growth where the level of treatment is tailored to the local specific needs rather than blindly applying treatment to complete plots. For instance, a large field may not require a uniform application of fertilizer; some localized area may require more while another requires less fertilizer. Similarly, irrigation parameters are affected by the local soil type, crop heterogeneity, etc. In general, the idea behind precision agriculture is that the grower should be able to save money by the judicious application of various treatments as required. When dealing with the targeted localized application of pesticides the benefits include not only large cost savings, but also reduced environmental pollution and hazard to man and animal.

In order to implement precision farming there is a need for methodology to detect and map the local conditions in a field and associate the mapped information with crop specific diagnoses. Remote sensing in general, and hyperspectral imaging in particular, can provide the tools to enhance precision agriculture. Problems within a particular crop typically shows up as stressed vegetation that can be detected with remote sensing tools. The challenge is to identify subtle spatial and spectral differences within a filed, and then relate these differences to causes of stress.

The present project focuses on the identification of pest infestation in cotton crop. Cotton is a challenging crop to raise and in the past couple of years, the entire U.S. cotton industry suffered major financial losses. Cotton farming economics is dominated by the cost of chemicals and pest management. As such, early detection of pest infestation could potentially be of great economic benefit.

2. AVIRIS Low Altitude Data

The cotton fields of interest in the present investigation are located in the southern region of the San Joaquin Valley (SJV) in California. These include commercial fields as well as experimental study plots operated by the U.S. Department of Agriculture, Agriculture Research Service (USDA/ARS), and by the University of California Extension Services. The land in the SJV is flat

at about 100 *m* above sea level, and at a flight altitude of about 3,500 *m*, the GSD is about 4 *m* with swath width of about 4 *km*. The AVIRIS flight took place on October 6, 1998, around local noon. AVIRIS data were geo-rectified and converted to a reflectance image by JPL. Two 20-*km* long flight lines were collected, out of which several segments were extracted. These segments contain cotton plots for which some control information is available including limited amount of ground truth and field history. This paper describes preliminary analyses conducted over two specific cotton plots shown in Fig. 1.

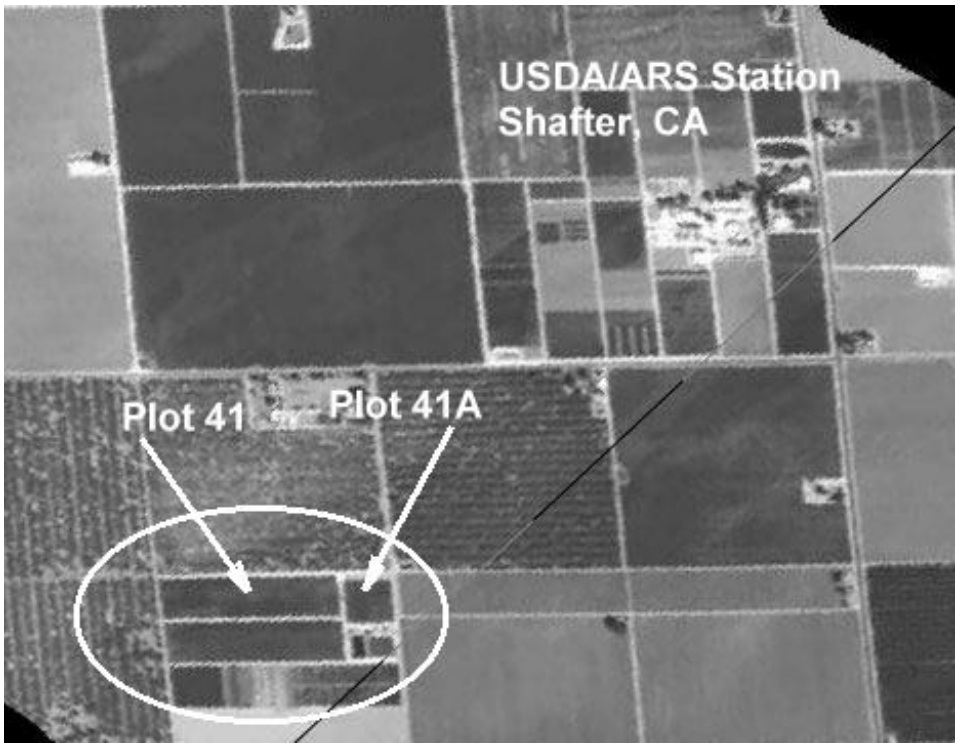

Figure 1. AVIRIS low altitude imagery and experimental cotton plots.

October is typically the time of the year for cotton picking in the SJV. About three weeks prior to picking the irrigation is stopped in preparation for the application of a defoliant agent. Defoliated cotton is more easily harvested. The flight date of 10 October was after irrigation had stopped, but before application of the defoliant agent. In practice, this would be too late in the season to affect any economic benefit. Also, because irrigation was stopped, the onset of water stress affects the data. However, these data provide great scientific value by allowing development and testing of analysis techniques that may be used to map subtle localized conditions across plots of specific crops.

3. Ground Work

Throughout the growth season which started in late May 1998, multispectral imagery was collected over the fields using the Shafter Airborne Multispectral Remote Sensing System (SAMRSS) instrument. This sensor package consists of three 1024×1024 CCD cameras equipped with filters simulating the first four TM bands. A fourth thermal infrared camera was also used. The SAMRSS GSD is about 0.6 *m*, and calibration panels are used for ground truth. The cotton fields, and the panels are shown in Fig. 2.

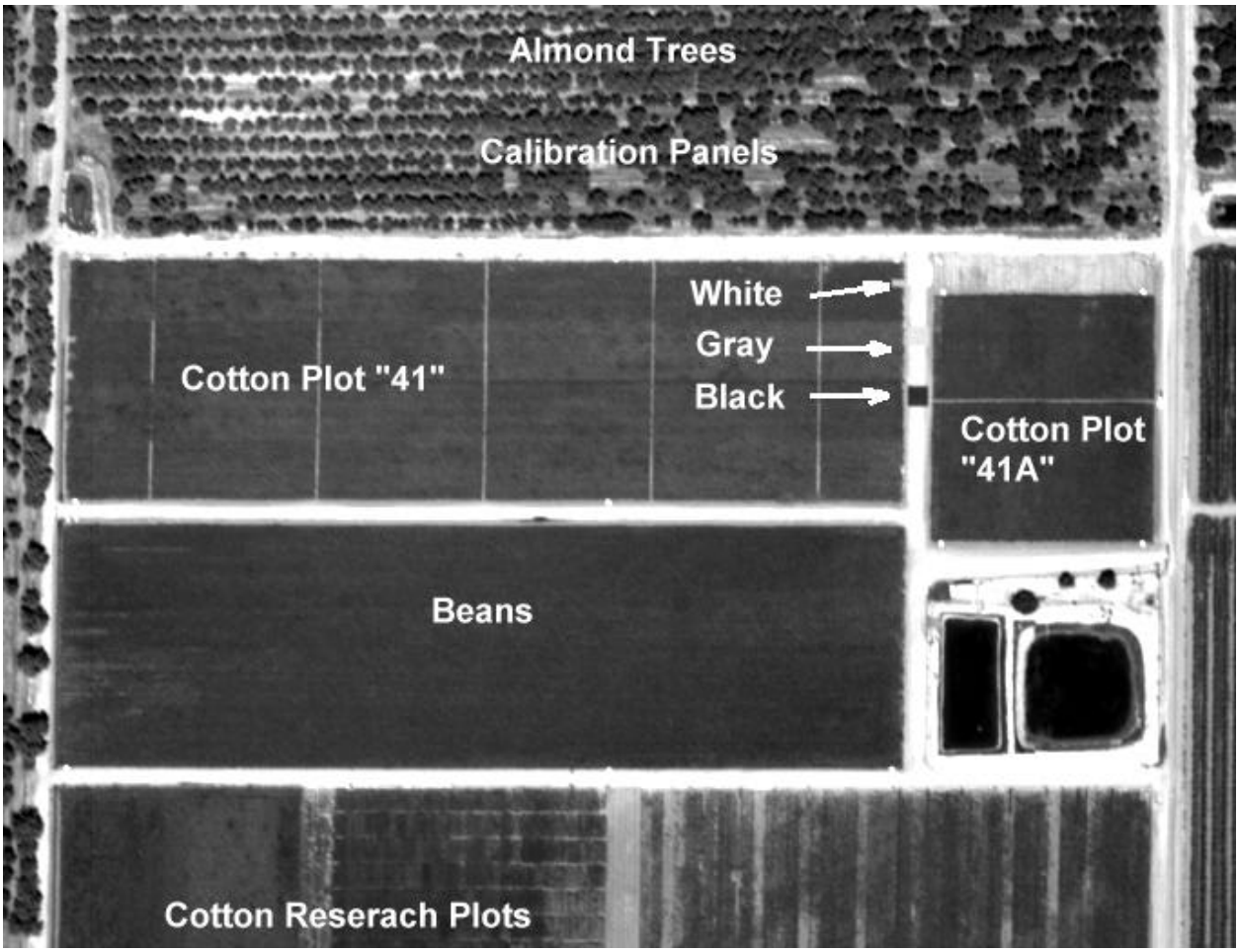

Figure 2. SAMRSS imagery of the experiment fields.

Plot 41A contains underground drip irrigation lines that allow control of water delivery to each individual row of plants. Plots 41 and 41A were used for irrigation studies and for (unplanned) pest infestation monitoring. Other parameters, such as soil water holding capacity, soil percent silt and clay, and electrical conductivity were also mapped for these fields as such parameters also affect plant growth and vigor. These maps will allow correlation of remote sensing derived quantities with known plant parameters.

The water stress can be clearly detected in the SAMRSS imagery during a period in August as depicted in Fig. 3. The information indicates that stress episodes are temporal and can not be detected unless the airborne imagery is collected within the relevant time period. Similarly, in Fig. 4 the damage caused by a spider mite infestation episode is depicted (Fitzgerald *et-al*, 1998).

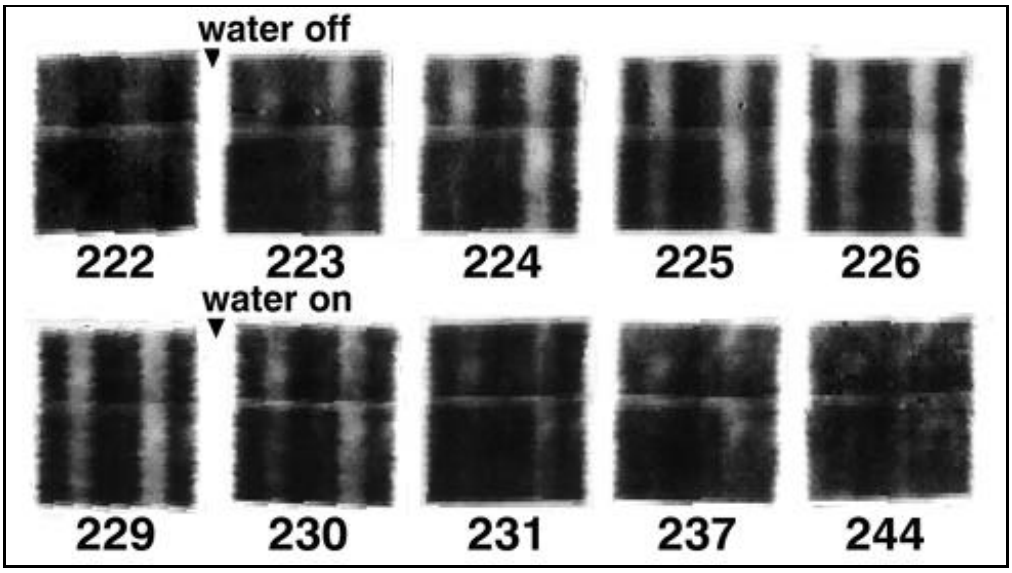

Figure 3. SAMRSS imagery showing water stress development during the seven days after water shut off, and full recovery within two weeks.

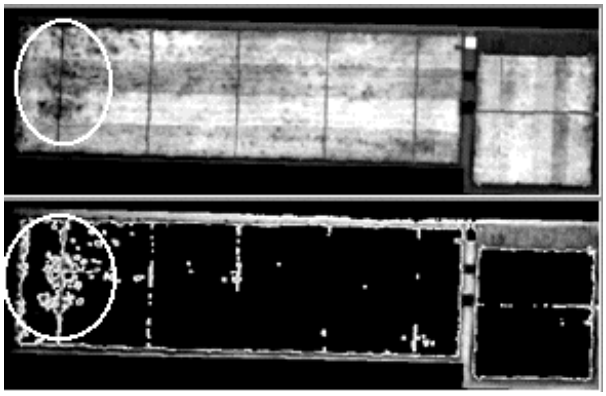
Figure 4. Spider mite infestation map.

4. Preliminary AVIRIS Analysis Results

As indicated earlier, the AVIRIS data were collected just before harvesting. Harvest was quantified with a real-time yield monitor equipped with GPS. The yield map is shown in Fig. 5 (the white strip in the middle indicates no data available). A preliminary analysis was done to correlate the yield in the plots with quantities derived from the AVIRIS imagery. Several quantities that were derived from the reflectance data are shown in Fig. 6. These include the conventional NDVI (Wasserman *et-al*, 1993), PRI (Gamon *et-al*, 1995), the second derivative of the chlorophyll red edge (Chen *et-al* 1996,1996*a*,), and water index, shown in Fig. 7. The indices, after carefully examining the data to select proper bands, were calculated from the following spectral bands: PRI 517 nm & 567 nm; DGVI: 626 nm to 798 nm; NDVI: 655 nm & 923 nm; and NWI: 971 nm & 1067 nm. Although qualitatively there seems to be some correlation between the indices maps and the yield, we were unable to derive a significant quantitative correlation.

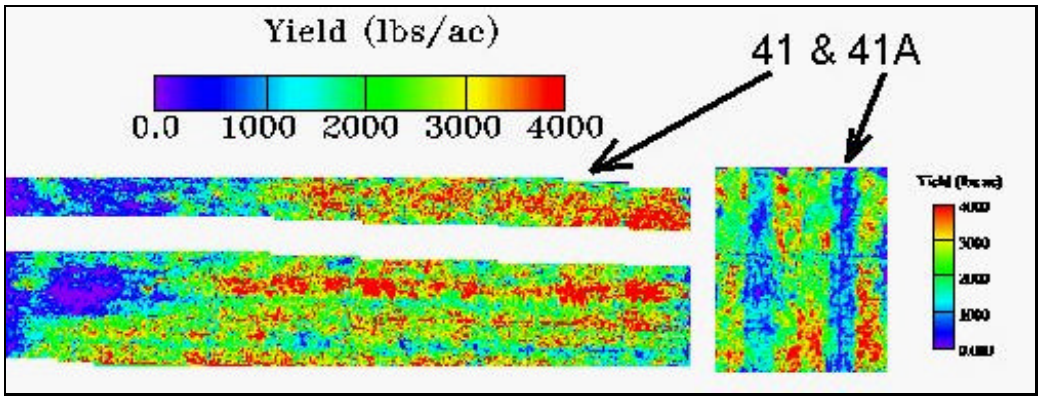

Figure 5. Real-time yield map.

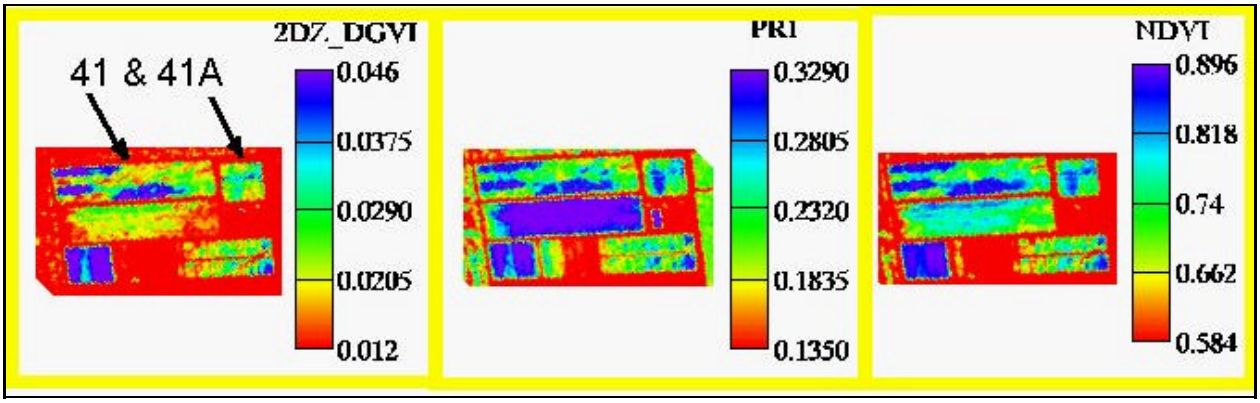

Figure 6. AVIRIS derived vegetation indices maps for the cotton plots.

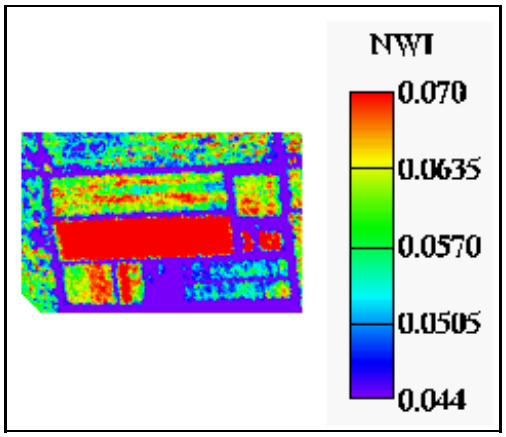

Figure 7. AVIRIS derived normalized water index map.

5. Summary, Conclusions, and Plans

The project described here is in its early stage. It was demonstrated, however, that the SAMRSS multispectral imagery, if collected in a timely manner, can detect various conditions relevant to cotton plant growth and vigor. The SAMRSS data however are in fixed broad bands and although the AVIRIS data are at lower spatial resolution, the high spectral resolution is expected to reveal more information.

Current work focuses on testing several other AVIRIS derived quantitative parameters that are related to the plant pathology. These include an improved definition of "greenness," monitoring the position of the red chlorophyll edge, and water content in the plants.

During the 1999 growth season more ground truth measurements will be conducted, and routine low altitude multispectral data collected. AVIRIS flights are expected at a more relevant period in the growth season. The new parameters will be then correlated with the ground and airborne multispectral data.

6. References

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