REMOTE SENSING OF VEGETATIVE COTTON TO ASSIST BOLL WEEVIL ERADICATION

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Abstract

Early identification of cotton fields is important for advancing boll weevil eradication progress in south Texas. Remote sensing has the potential for this purpose over diverse habitats and large geographic regions. The objectives of this study were to develop practical methods for identifying cotton fields from airborne imagery before cotton plants start to bloom. Airborne multispectral imagery with 0.1- and 0.2-m pixel sizes was acquired four times along a 12-km length of the Brazos Valley near College Station, TX in 2013. Supervised classification techniques were applied to a single image and a mosaicked image, both with 0.2-m pixels, to distinguish planted cotton from other crops and cover types. The original 0.2-m, 16-bit image was degraded to images with 1- and 2-m spatial resolutions and 8-bit spatial resolution. These resolution-reduced images were almost as effective for identifying cotton fields as the original image. As an application example, a mosaicked 8-bit image with 2-m pixel size was classified to differentiate cotton fields from other cover types. These results will help eradication program managers quickly and efficiently identify cotton fields and potential areas for volunteer and regrowth cotton plants, thus improving the effectiveness of eradication and reducing the risk of re-infestation.

Introduction

Cotton plants serve as a source of food and reproduction for boll weevils. Thus, early identification of cotton fields and timely detection of volunteer and regrowth cotton plants are important for improving the success of boll weevil eradication in south Texas. Volunteer and regrowth cotton plants not only serve as a host for boll weevils, but also cause yield loss in grain crops due to the competition for water and nutrients (Morgan et al., 2011). Remote sensing has the potential to identify cotton fields and volunteer and regrowth cotton plants over large geographic regions. Airborne and satellite images have been successfully used to distinguish planted cotton from other crops over large geographic areas in south Texas (Yang et al., 2007 and 2011). However, limited research has been done on the use of remotely sensed imagery for identifying cotton fields before cotton plants start to bloom. The objectives of this study were to develop practical methods for identifying cotton fields from airborne imagery before cotton plants started to bloom and to examine the effects of spatial, spectral and radiometric resolutions on image classification results.

Materials and Methods

Study Site

A rectangular area centered along Highway FM 50 near College Station, TX with at least two dozen cotton fields and other crops and cover types was selected as the study site. The area has a length of approximately 12 km and a width of approximately 1 km with the center coordinates (96°29'33" W, 30°34'45" N).

Airborne Multispectral Image Acquisition

A two-camera imaging system was used to take images from the study area. The system consisted of two Canon EOS 5D Mark II digital cameras with a 5616 x 3744 pixel array (Canon USA Inc., Lake Success, NY). One camera captured normal color images with blue, green and red bands, while the other camera was equipped with a 720-nm long-pass filter to obtain near-infrared (NIR) images. The two cameras were mounted next to each other to cover essentially the same geographic area. A remote control device was used to trigger both cameras simultaneously for image acquisition. Images from each camera were stored in 16-bit RAW and 8-bit JPEG files in a CompactFlash card. Images were captured at altitudes of 305 and 610 m (1000 ft and 2000 ft) to achieve ground pixel sizes of 0.1 and 0.2 m, respectively. A Cessna 206 single-engine aircraft was used to acquire imagery on 7, 23, and 30 May and 17 June 2013. However, only some of the images with 0.2-m pixel size taken on 30 May were analyzed and used in this paper.
**Image Alignment**
An image-to-image registration procedure was used to align the color and NIR images. Eight to ten common control points approximately evenly distributed on both the color and NIR images were identified to establish the transformation model. A first-order polynomial transformation model with nearest neighborhood resampling was used to rectify the NIR image to the color image. The rectified NIR image was then merged with the color image to create the four-band image. All procedures for image rectification and merging were performed using ERDAS Imagine (Intergraph Corporation, Madison, AL).

**Generating Images with Different Spatial and Radiometric Resolutions**
The original 0.2-m image was aggregated by factors of 5 and 10 to generate images with 1- and 2-m resolutions, respectively. The value for each output pixel was the mean of the input pixels that the coarser output pixel encompassed. The original 16-bit image with digital counts ranging from 0 to 65535 were converted to 8-bit image using the formula $DC_{8-bit} = DC_{16-bit} \times 255 / 65535$.

**Image Mosaicking**
Each 0.2-m image covered a rectangular area of approximately 1123 m x 745 m. Ten consecutive images with about 60% overlap were stitched together using Adobe Photoshop CC (Adobe Systems Incorporated, San Jose, CA) to create a mosaicked image. To minimize the image size, the 8-bit JPEG images were used for the mosaicking.

**Image Classification**
Four supervised classifiers, including minimum distance, Mahalanobis distance, maximum likelihood, and spectral angle mapper (SAM) (ERDAS, 2010; Kruse et al., 1993) were selected for image classification. The original 4-band, 0.2-m, and 16-bit image and all the derived images, including 1- and 2-m images, the normal color images, and the color infrared (CIR) images and 8-bit images were classified. Training samples for all major cover types were defined on the images and their spectral signatures were derived. One single image and all its derived images were classified into five classes: cotton, corn, dense forage, sparse forage, and bare soil/roads. The mosaicked image was classified into six classes: cotton, corn, soybean, dense forage, sparse forage, and bare soil/roads. Image classification was performed using the image processing software ENVI (Research Systems, Inc., Boulder, CO).

**Cotton Growth Measurements**
Plant height, width and average nodes were measured on 10 randomly selected plants on the same date the images were taken. The cotton crop was predominately at the pinhead to the third-grown square stage.

**Results and Discussion**
Figure 1 shows the color and CIR images acquired at 610 m with a pixel size of 0.2 m. On the normal color image, corn and dense forage had a darker green color, while cotton fields had a light gray color with green plants along the rows. On the CIR image, corn and dense forage exhibited a reddish-magenta tone, while cotton fields had a grayish or cyanish color. Since cotton plants were relatively small (canopy width from 19-32 cm), cotton fields had a dominant tone of background soil.

![Figure 1](image1.png)  ![Figure 1](image2.png)

Figure 1. A normal color image (left) and color-infrared (CIR) image (right) taken at 610 m with a pixel size of 0.2 m from a cotton-growing area near College Station, Texas in 2013.
Figure 2 shows four maximum likelihood-based classification maps with two different spatial resolutions and two different band combinations for the imaging area shown in Figure 1. Visually, there were very small differences in classification results between the 0.2- and 2-m pixel resolutions or between the 4-band and 3-band color images, indicating that coarser-resolution images and the simple normal color images can be used to distinguish cotton fields from other crops. Cotton fields were generally correctly identified with some misclassified pixels within fields.

Figure 2. Maximum-likelihood-based classification maps with two different spatial resolutions and two different band combinations for the imaging area shown in Figure 1. (Red-Cotton, Green-Corn, Blue-Dense Forage, Yellow-Sparse Forage, Cyan-Bare soil/Roads)

Table 1 summarizes the classification results at three spatial resolutions and three different band combinations based on the four supervised classifiers. Among the 36 classifications, estimated total percentage cotton growing area ranged from 29% to 52%. Based on visual comparison of the classification maps among the four classifiers, the maximum likelihood classifier provided more accurate classification. The other three classifiers tended to underestimate the cotton growing areas. Among the three spatial resolutions, the classification results were similar for each band combination and each classifier. Among the three band combinations, the results were also similar for each spatial resolution and each classifier. These results indicate that either a color or a CIR composite with coarser spatial resolution will be sufficient for distinguishing cotton fields from other crops and cover types. Results also showed that the 8-bit image estimated essentially the same results as the 16-bit image.
Table 1. Cotton growing area estimates (%) based on a 16-bit image at three different spatial resolutions and three different band combinations using four supervised classifiers

<table>
<thead>
<tr>
<th>Image Classifier</th>
<th>0.2-m</th>
<th>1-m</th>
<th>2-m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4-Band</td>
<td>Color</td>
<td>CIR</td>
</tr>
<tr>
<td>MD*</td>
<td>33.94</td>
<td>35.21</td>
<td>29.13</td>
</tr>
<tr>
<td>MAHD</td>
<td>40.39</td>
<td>40.47</td>
<td>42.74</td>
</tr>
<tr>
<td>ML</td>
<td>48.90</td>
<td>48.57</td>
<td>47.95</td>
</tr>
<tr>
<td>SAM</td>
<td>44.32</td>
<td>41.54</td>
<td>41.70</td>
</tr>
</tbody>
</table>

* MD=Minimum distance, ML=Maximum likelihood, MAHD=Mahalanobis distance, SAM=Spectral angle mapper.

Figure 3 shows the mosaicked image (2660 m x 966 m) and the maximum likelihood-based classification for the image. All the major fields were correctly distinguished based on ground verification, even though some areas within fields were misclassified. Table 2 presents classification results for the mosaicked image under two spatial resolutions. Among the eight classifications, estimated total percentage cotton growing area ranged from 33% to 50%. Based on visual comparison of the classification maps among the four classifiers, the maximum likelihood classifier also provided more accurate classification for the mosaicked image.

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Figure 3. Mosaicked color image (top) and its maximum likelihood-based classification map (bottom). (Red-Cotton, Green-Corn, Purple-Soybean, Blue-Dense Forage, Yellow-Sparse Forage, Cyan-Bare soil/Roads)
Table 2. Cotton growing area estimates (%) based on an 8-bit mosaicked image at two different spatial resolutions using four supervised classifiers

<table>
<thead>
<tr>
<th>Image Classifier</th>
<th>0.2-m</th>
<th>2-m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum distance</td>
<td>33.90</td>
<td>34.18</td>
</tr>
<tr>
<td>Mahalanobis distance</td>
<td>33.26</td>
<td>33.61</td>
</tr>
<tr>
<td>Maximum likelihood</td>
<td>46.37</td>
<td>50.05</td>
</tr>
<tr>
<td>Spectral angle mapper</td>
<td>37.53</td>
<td>39.77</td>
</tr>
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</table>

**Conclusions**

The results from this study showed that cotton fields can be successfully identified at relatively early growth stages. Spatial resolution and radiometric resolution had little effect on correct identification of cotton fields. Either a color composite or a CIR composite from the 4-band image provided similar results to the 4-band image. These results indicate that the simple 8-bit color image can be used for early identification of cotton fields. However, images with full spatial, spectral and radiometric resolutions would be useful for distinguishing volunteer and regrowth cotton plants from other surrounding non-cotton plants. More research is needed to examine how spatial and spectral resolutions affect the identification of cotton fields and volunteer and regrowth cotton plants at early stages of plant growth and under various growing conditions.

**Acknowledgements**

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**References**


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