# EARLY IDENTIFICATION OF COTTON FIELDS USING MOSAICKED AERIAL IMAGERY

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## Abstract

Early identification of cotton fields is important for advancing boll weevil eradication progress and reducing the risk of re-infestation. Remote sensing has been used for crop identification for decades, but limited work has been reported on early identification of cotton fields. The objective of this study was to evaluate mosaicked aerial imagery for identifying cotton fields before cotton plants start to bloom. A two-camera imaging system was used to acquire RGB and NIR images with a pixel array of 5616 × 3744 over an 8 km by 14.5 km (5 mi by 9 mi) cropping area near College Station, TX in the 2014 growing season. The images were acquired at 3048 m (10000 ft) above ground level along two flight lines to achieve a pixel resolution of 1.0 m. The individual images were mosaicked as one single image and then classified into different crop and cover types using supervised classification techniques. Preliminary results showed that the mosaicked color image was able to accurately differentiate cotton fields from other crop and cover types. These results will be useful for boll weevil eradication program managers to quickly and efficiently identify cotton fields and potential areas for volunteer and regrowth cotton plants.

## Introduction

The boll weevil (*Anthonomus grandis* Boheman) is now eradicated from all cotton-producing states in the U.S. except for the Rio Grande Valley of Texas. However, the cotton growing areas, especially those adjacent to the lower Rio Grande Valley, will remain susceptible to re-infestation from boll weevil migration. Therefore, early identification of fields planted in cotton is critical for eradication program managers to effectively monitor boll weevil populations and treat the respective fields in a timely manner.

Remote sensing has the potential to identify cotton fields over large geographic regions. Remote sensing has been successfully used to distinguish planted cotton from other crops over large geographic areas in south Texas (Yang et al., 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 mosaicked airborne imagery prior to cotton bloom and to examine the effect of spatial resolutions on image classification results.

## Materials and Methods

An 8 km by 14.5 km (5 mi by 9 mi) rectangular cropping area with the center coordinates (96°29'33" W, 30°34'45" N) near College Station, TX was selected as the study site (Figure 1). Two major crops, cotton and corn, and several other crops were planted in the study area.

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 RGB color images, while the other camera was equipped with a 720-nm long-pass filter to obtain near-infrared (NIR) images. A GPS receiver was attached to the RGB camera to geotag the images. Images from each camera were stored in 16-bit RAW (CR2) and 8-bit JPEG files in a CompactFlash card.

Images were captured at 3048 m (10000 ft) above ground level along two flight lines spaced approximately 3200 m (10500 ft) apart. Each image covered a ground area of 5486 m × 3658 m (18000 ft × 12000 ft) with a ground pixel size of 1.0 m. A Cessna 206 single-engine aircraft was used to acquire imagery on 15 and 29 May, and 10 and 30 June 2014. There was at least a 40% overlap between images along and between the flight lines. Only the RGB images taken on June 10 were used in this paper. At that time, the cotton plants were predominately at the pinhead to the third-grown square stage with an average height of 20-54 cm and an average width of 22-55 cm.

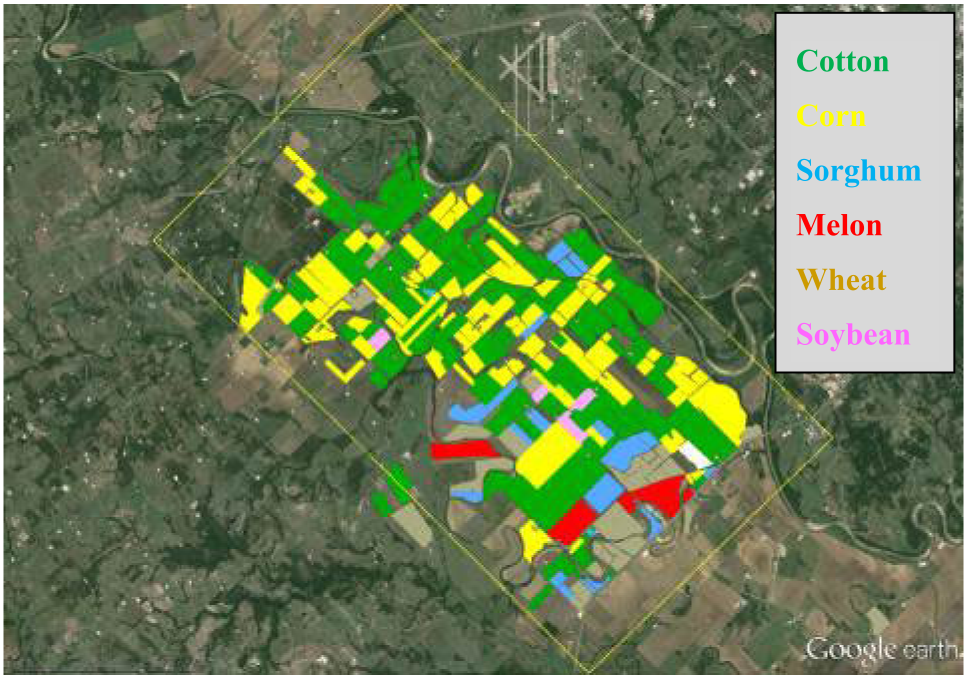


Figure 1. An 8 km by 14.5 km (5 mi by 9 mi) cropping area (yellow box) with color-coded crop types near College Station, TX.

Figure 2 shows the geotagged color images (thumbnails) taken on June 10, 2014 plotted in Google Earth (Google Inc., Mountain View, CA). A total of 32 images falling within the study area (yellow box) were processed.


Figure 2. Geotagged color images (thumbnails) plotted in Google Earth. The images were acquired at 3048 m (10000 ft) above ground level near College Station, TX on June 10, 2014.

The 32 RAW RGB images were first corrected for vignetting and then converted to 8-bit Tiff using Digital Photo Professional software (Canon USA Inc., Lake Success, NY). For image mosaicking, professional image processing software generally requires the input images are georeferenced and contain map and projection information. To avoid the time-consuming process to georeference all 32 images, the general-purpose Adobe Photoshop CC (Adobe Systems Incorporated, San Jose, CA) was used to stitch the images together as one mosaicked image. The mosaicked image was then georeferenced using 15 ground control points extracted from Google Earth.

The mosaicked 1-m image was degraded by factors of 10, 20 and 30 to generate images with 10-, 20-, and 30-m resolutions, respectively. The value for each output pixel was the mean of the input pixels that the coarser output pixel encompassed. The supervised maximum likelihood classifier (Intergraph Corporation, 2013) was selected for image classification. Training sample areas from all crop and cover types were defined on the images and their spectral signatures were derived. The 1-m image and the three coarse-resolution images were classified into eight classes: cotton, corn, sorghum, melon, wheat, pasture, trees, and bare soil/roads. The classification maps were further regrouped to cotton and non-cotton categories.

For accuracy assessment of the two-category classification maps, 100 points were generated and assigned to the two categories in a stratified random pattern. The ground-truthing map shown in Figure 1 was used for verification. Classification accuracy measures, including overall accuracy, kappa coefficient, producer's accuracy and user's accuracy, were calculated (Congalton and Green, 1999). All procedures for image rectification, classification and accuracy assessment were performed using ERDAS Imagine software (Intergraph Corporation, Madison, AL).

## Results and Discussion

Figure 3 shows the mosaicked RGB image with correct orientation. The image looks continuous and seamless despite the fact that the individual images were not georeferenced for image stitching.

Figure 3. Mosaicked color image from the 32 images shown in Figure 2.

Based on the 15 control points extracted from Google Earth using a second-order transformation, the root mean square (RMS) error for georeferencing the mosaicked image was 26.7 m (88 ft). This error is relatively high and may not be acceptable if the image is used to locate specific sites, but it will be more than sufficient to locate a cotton field.

Figure 4 shows a maximum likelihood-based classification map for the 1-m mosaicked image. A quick comparison of the classification map with the ground survey map shown in Figure 1 indicates that the classification map correctly identifies most of the cotton fields in the imaging area.

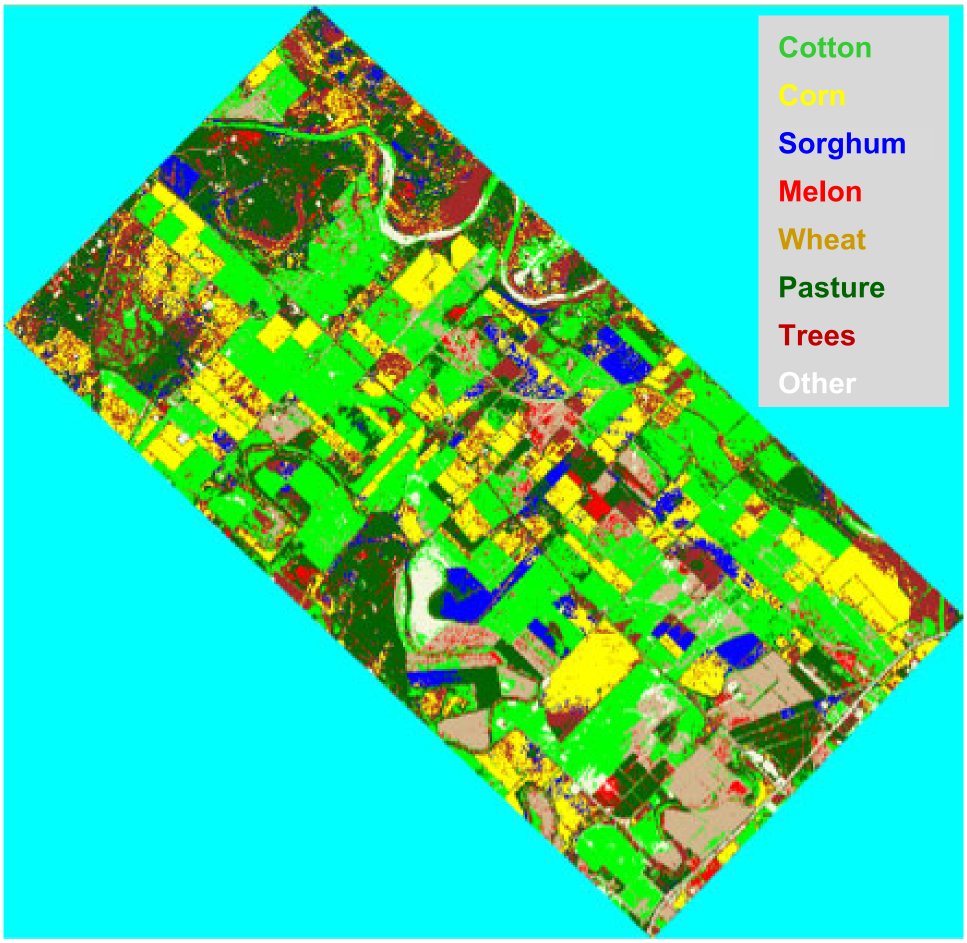


Figure 4. Classification map using maximum likelihood classifier.

Table 1 shows the accuracy assessment results for the classification map. The overall accuracy of the classification map was 91%, indicating that 91% of the image pixels were correctly identified in the classification map. The producer's accuracy (a measure of omission error), which indicates the probability of actual areas being correctly classified, was 82% for the cotton category and 92% for the non-cotton category. The user's accuracy (a measure of commission error), which is indicative of the probability that a category classified on the map actually represents that category on the ground, was 90% for cotton areas and 91% for non-cotton areas. The kappa estimate for this field was 0.860, indicating that the classification achieved an accuracy that is 86% better than would be expected from random assignment of pixels to categories.

Figure 5 shows the four classification maps from the mosaicked images with 1-, 10-, 20-, and 30-m spatial resolutions. Visually, they look very similar to each other, indicating that coarser-resolution images may be used to accurately distinguish cotton fields from other crops.

Table 1. Accuracy assessment results for a two-zone classification map of a normal color image for identification of cotton fields in a cropping area near College Station, TX.

| Classified Category | Actual Category Cotton | Non-Cotton | Total | User's Accuracy |
|---|---|---|---|---|
| Cotton | 27 | 3 | 30 | 90.0% |
| Non-Cotton | 6 | 64 | 70 | 91.4% |
| Total | 33 | 67 | 100 | |
| Producer's Accuracy | 81.8% | 91.9% | | |

Overall accuracy = (27 + 64)/100 = 91.0%. Kappa = 0.792.

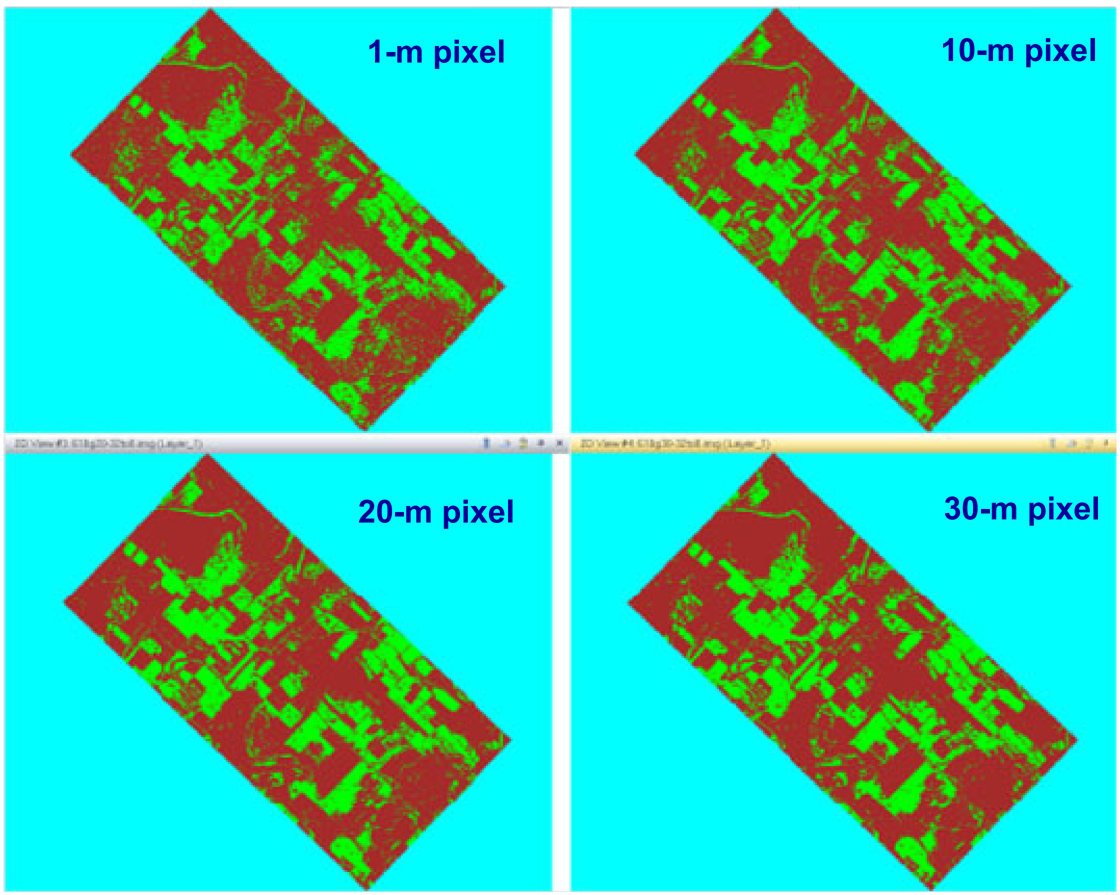


Figure 5. Merged two-category classification maps for four different pixel sizes.

Table 2 gives the estimates of cotton and non-cotton areas based on the four classification maps shown in Figure 4. The four maps provide essentially the same estimates with approximately 2520 ha (6220 ac) of cotton and 6050 ha (14950 ac) of non-cotton in the study area. Cotton accounted for about 30% of the total area.

Table 2. Estimates of cotton and non-cotton areas based on four classification maps derived from mosaicked images in four spatial resolutions.

| Pixel Size | Cotton | | | Non-Cotton | | |
|---|---|---|---|---|---|---|
| (m) | ha | ac | (%) | ha | ac | (%) |
| 1 | 2518 | 6222 | 29.4 | 6051 | 14951 | 70.6 |
| 10 | 2572 | 6356 | 30.0 | 6007 | 14842 | 70.0 |
| 20 | 2581 | 6377 | 30.1 | 6006 | 14840 | 69.9 |
| 30 | 2575 | 6362 | 29.9 | 6038 | 14920 | 70.1 |

Total area = 8569 ha (21173 ac).

## Conclusions

The results from this study showed that cotton fields can be accurately identified at relatively early growth stages using mosaicked aerial RGB imagery. Change in pixel sizes from 1 to 30 m had little effect on image classification results. Airborne RGB images and mosaicked images will be a useful tool for boll weevil eradication program managers to quickly and efficiently identify cotton fields and potential areas for volunteer and regrowth cotton plants. Research is needed to examine both high resolution (1-5 m) and moderate resolution satellite imagery (30 m) for early identification of cotton fields.

## Acknowledgements

This project was partly funded by Cotton Incorporated in Cary, NC. The authors wish to thank Denham Lee and Fred Gomez of USDA-ARS at College Station, TX for taking the multispectral imagery for this study, and Derrick Hall, Cody Wall, and Jose Perez of USDA-ARS at College Station, TX for ground measurements and verification.

## Disclaimer

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