COMPARISON OF SENTINEL-2, LANDSAT, AND AIRBORNE IMAGERY FOR IDENTIFICATION OF COTTON FIELDS FOR BOLL WEEVIL ERADICATION

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Abstract

Our previous studies have demonstrated that both airborne and satellite images with submeter and 10-m resolution, respectively, are effective for identification of cotton fields, which is important for the boll weevil eradication program in Texas. In this study, both 10-m Sentinel-2 and 30-m Landsat satellite images were evaluated and compared with airborne imagery for identifying cotton fields during cotton squaring to blooming stages. Airborne color and near-infrared images were acquired over a 10 km by 11 km study area near Snook, Texas on 17 June 2020. Among the Sentinel-2 and Landsat images, two cloud-free images were identified for the study area within a week of the airborne image acquisition, including one Sentinel-2 image acquired on 10 June and one Landsat 7 image acquired on 16 June. The airborne images from the study area were mosaicked, and the airborne mosaic and the two satellite images were each classified into different crop types using multiple classification techniques. Accuracy assessment were performed to compare the classification maps with ground surveyed field maps. Preliminary results showed that both Sentinel-2 and Landsat imagery had similar performance to airborne imagery for distinguishing cotton from other crops. Efforts are underway to determine if cotton fields can be detected at earlier growth stages with satellite images collected over the study area in May 2020. The results and methodologies from this study will provide boll weevil eradication program managers with technology and some guidelines to remotely identify cotton fields during early and mid-growth stages over large geographic areas.

Introduction

Although boll weevil has been eradicated from all cotton-producing states in the U.S. except for the Lower Rio Grande Valley of Texas, cotton production areas adjacent to the Valley and Mexico remain susceptible to re-infestation. During 2020, over 40,000 weevils had been captured and over 525,000 ha (1.3 million acres) had been treated in the Valley (Texas Boll Weevil Eradication Foundation, 2020). Therefore, early identification of cotton fields is critical for eradication program managers to effectively monitor boll weevil populations and to treat the respective fields promptly. Yang et al. (2017) evaluated aerial imagery for identifying cotton fields before cotton started blooming and their results demonstrated that aerial images (1-m resolution) allowed for cotton field identification with an overall accuracy of more than 90%. Yang and Suh (2020) evaluated 10-m Sentinel-2 satellite imagery for identification of cotton fields during the growing season. Although excessive rainfall and different planting dates in 2019 made it difficult to distinguish some cotton fields from other crops and fallow fields, preliminary results showed that Sentinel-2 imagery was promising for cotton field identification at relatively early growth stages. While aerial imagery is accurate and feasible for relatively small growing areas, satellite imagery would be more practical for large geographic regions. The objective of this study was to compare both 10-m Sentinel-2 and 30-m Landsat imagery with submeter airborne imagery for identifying cotton fields.

Materials and Methods

Study Site

This study was conducted over a 10 km × 11 km cropping area along the Brazos River near Snook, Burleson County, Texas (Figure 1). All the fields were ground surveyed to confirm crop types and all field boundaries were digitized on Google Earth initially and were then verified and modified based on the airborne imagery. The total area of all the fields in the study area was 5,243 ha and three major crops accounted for 90% of the total area with 2,418 ha (46.1%) of cotton, 1,138 ha (21.7%) of corn, and 1215 ha (23.2%) of sorghum. The areas for soybean, watermelon, sunflower and fallow were 56 ha (1.1%), 175 ha (3.3%), 99 ha (1.9%) and 141 ha (2.7%), respectively.

Airborne Image Acquisition and Mosaicking

A Cessna 210 aircraft equipped with a two-camera imaging system was used for image acquisition. The imaging system consisted of two Nikon D850 digital cameras with 8256 × 5504 pixels. One camera captured normal RGB color images, while the other camera modified with an 830-nm long band-pass filter obtained near-infrared (NIR) images. A GPS receiver attached to each camera was used to geotag the images. Images were captured at 2,590 m (8,500) ft above ground level at 225 kph (140 mph). With the predetermined flight height and flight speed as well as a 65% side overlap and an 85% forward overlap, six flight lines spaced at an interval of 1,630 m (5,355 ft) were created for a 10 km by 18 km (6 mile by 6.6 mile) imaging area (7 km longer than the study area). Figure 1 shows the flight lines across the study area. The images were captured at 8 s intervals and a total of 230 pairs of RGB and NIR images were obtained around noon time on 17 June 2020 under sunny conditions. Pix4DMapper (Pix4D SA, Lausanne, Switzerland) was used to mosaic the RGB and NIR images with a pixel size of 0.56 m. The RGB and NIR orthomosaics were then stacked into a four-band mosaic image and resampled to 1-m pixel resolution using Erdas Imagine (Intergraph Corporation, Madison, Alabama).

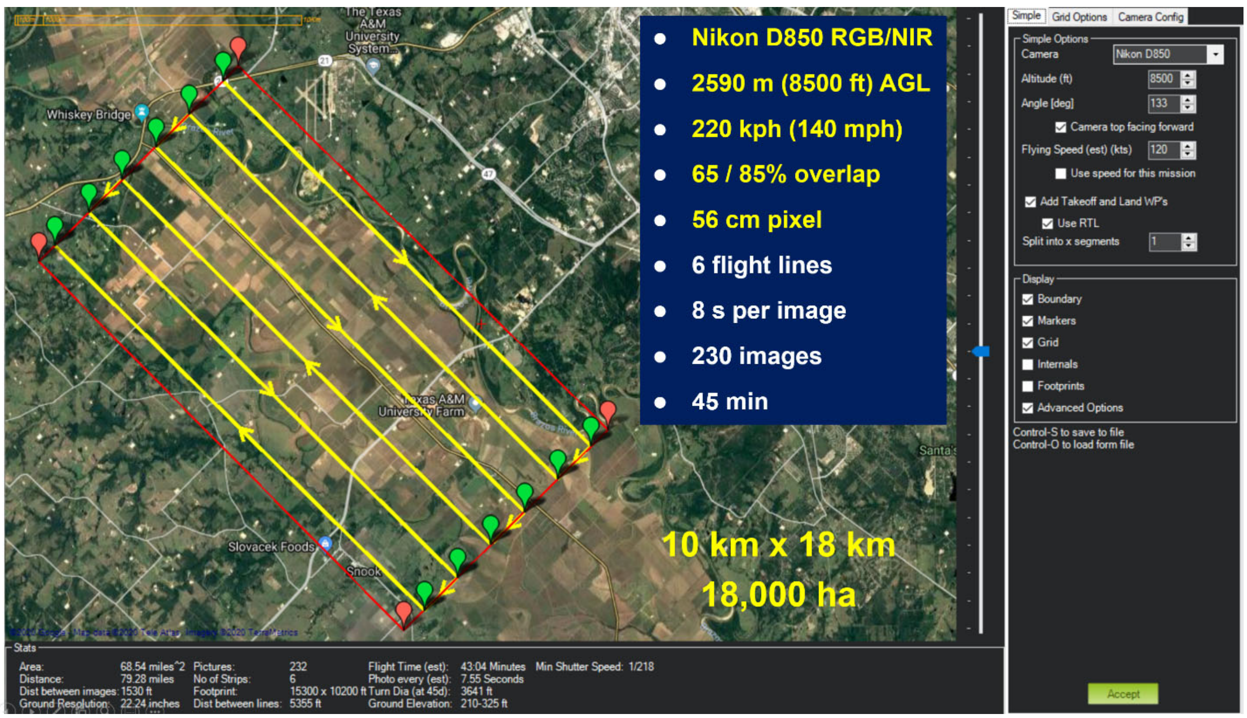

Figure 1. Airborne image acquisition and flight parameters over a 10 km by 18 km imaging area (larger than the study area) near Snook, Texas.

Satellite Images

For the 2020 growing season, five cloud-free satellite images for the study area were acquired, including two Sentinel-2 images (May 6 and June 10), two Landsat 7 images (June 16 and August 3), and one Landsat 8 image (May 13). Each Sentinel-2 image has a ground coverage of 110 km by 110 km, while the Landsat images each cover approximately 170 km by 170 km. Sentinel-2 offers 13 spectral bands in the 443 to 2,190 nm range with three visible bands (blue, green, red) and one NIR band at a spatial resolution of 10 m, four red edge bands and two SWIR bands at 20 m, and three atmospheric correction bands at 60 m. Only the four 10-m Sentinel-2 bands were used in this study. Similarly, although Landsat 7 and Landsat 8 provide eight bands and 11 bands, respectively, only the four visible to NIR bands (blue, green, red and NIR) at 30 m resolution were used. Both Sentinel-2 and Landsat data are provided free of charge to all users. For this manuscript, only the 10 June Sentinel-2 image and the 16 June Landsat 7 image acquired within one week of the 17 June airborne image were selected for analysis and comparison.

Field Boundaries and Ground Survey

Field boundary polygons digitized in 2019 were used for the 2020 study. As some fields were divided for planting different crops, the airborne imagery was used as the background image to update the field polygons and to add additional crop fields that were found in the ground survey. An updated shapefile with the 2020 crop survey information was created using ArcMap (ESRI, Redlands, California). Texas Boll Weevil Eradication Foundation (TBWEF) has developed a Geographic Information System (GIS) database that contains cotton field boundaries and historical crop information. Ground surveys are conducted to determine cotton fields each year. Since cotton is rotated with other crops, field boundary files for both cotton and other crops can be generated from the TBWEF GIS database for cotton growing areas in Texas.

Image Classification and Accuracy Assessment

As the boundaries for all the fields in the study area were available, image classification was conducted only within all the fields. The classes defined for image classification included the six crops (cotton, corn, sorghum, soybean, watermelon, and sunflower) and one non-crop type (fallow). Due to the large variability within each field and different planting dates and management practices, 2 to 13 fields or subclasses within each class type were selected as training samples to create the signatures for image classification. One signature file with 41 subclasses was created for each of the three images (17 June airborne, 10 June Sentinel-2 and 16 June Landsat 7). Three types of classification methods were evaluated for image classification, including traditional supervised classifiers, machine learning classifiers and deep learning algorithms. In this manuscript, only the results based on the traditional maximum likelihood classifier are reported for performance comparison of the two satellite images and the airborne image.

Image classification was performed using Erdas Imagine. The 41 subclasses in each classification map were merged into the seven classes. The merged classification maps were then converted to polygons in shapefiles and overlaid on the field boundary shapefile in ArcMap for spatial analysis. Because of within-field variability and spectral similarity between the classes, multiple classes coexisted within the same field on all classification maps. To ensure that each field was classified to one dominant class, all the minor classes were reassigned to the majority class in the field. For accuracy assessment, each reassigned or filtered classification map was compared with the ground survey map to create a classification error matrix. Classification accuracy statistics including overall accuracy, producer's accuracy, user's accuracy, and kappa coefficients were calculated based on each error matrix.

Results and Discussion

Figure 2 shows the original classification map and the filtered map for the airborne image. A quick comparison of the classification maps with the ground survey map indicates that the classification maps correctly identified most of the cotton fields. However, some cotton fields were misclassified due to the spectral similarity with other crops in the areas with small plants.

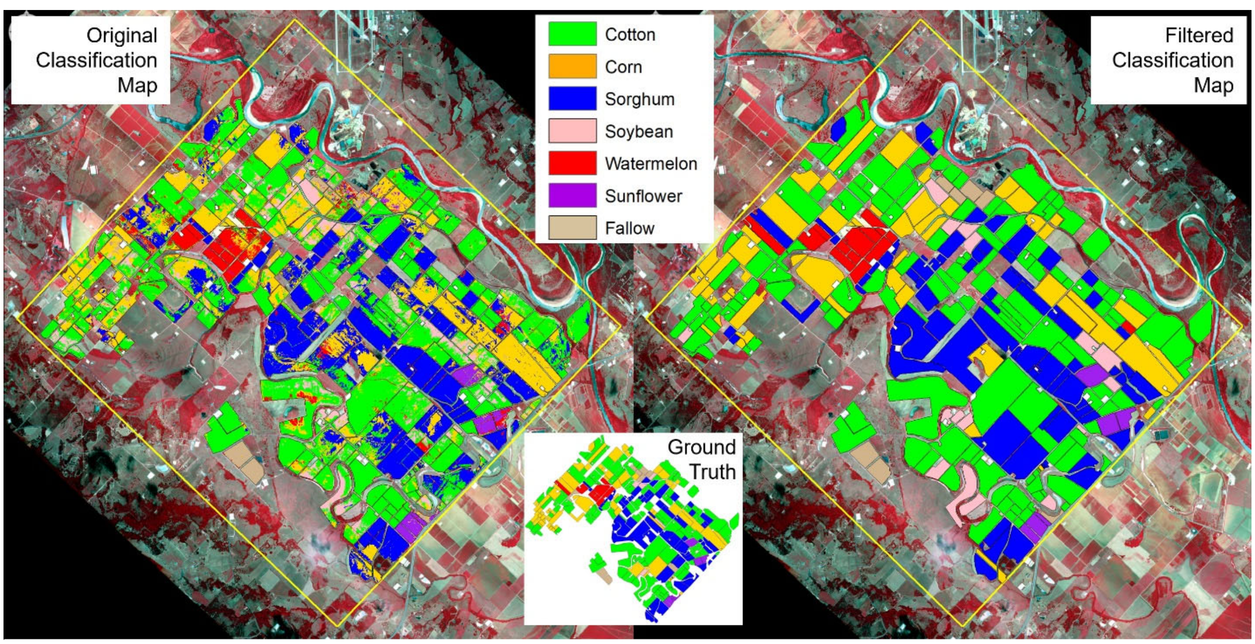

Figure 2. Original and filtered classification maps for an airborne image acquired on 17 June 2020 for a 10 km by 11 km area near Snook, TX.

Figures 3 and 4 show the filtered classification maps for the Sentinel-2 and Landsat 7 images, respectively. Similarly, both classification maps correctly separated a large majority of the cotton fields from the other crop fields. Table 1 summarizes the accuracy assessment results for the three filtered classification maps. The overall accuracy was 83.2% for the airborne image, 89.7% for the Sentinel-2 image and 82.1% for the Landsat 7 image, indicating 83.2%, 89.7% and 82.1% of the field areas were correctly classified by the respective images. The producer's accuracy for cotton, which is a percentage of correctly classified cotton areas on the map over the actual cotton areas on the ground, was 87.6%, 84.5% and 82.5% for the three respective images. On the other hand, the user's accuracy for cotton, which is a percentage of correctly classified cotton areas on the map over all the classified cotton areas on the map, was 87.4% 95.8% and 92.4% for the respective images. Both producer’s accuracy and user’s accuracy have to be considered to determine the accuracy of the classification maps. In this regard, the classification map from the airborne image had balanced producer’s and user’s accuracy. Although the classifications maps from the two satellite images had higher user’s accuracy, they had slightly lower producer’s accuracy than the airborne image-derived map. Nevertheless, the three types of images provided similar classification performance.

The classification results for soybean were very poor for the three images. Soybean accounted for only 1.1% of the total hectarage in the study area, but its area was overestimated in all three classification maps due to its spectral similarity to cotton at this growth stage. Therefore, if soybean was not considered as a class, both the overall accuracy and the classification accuracy for cotton would improve. More analysis is being performed to assess how elimination of soybean and other minor classes affect the classification results.

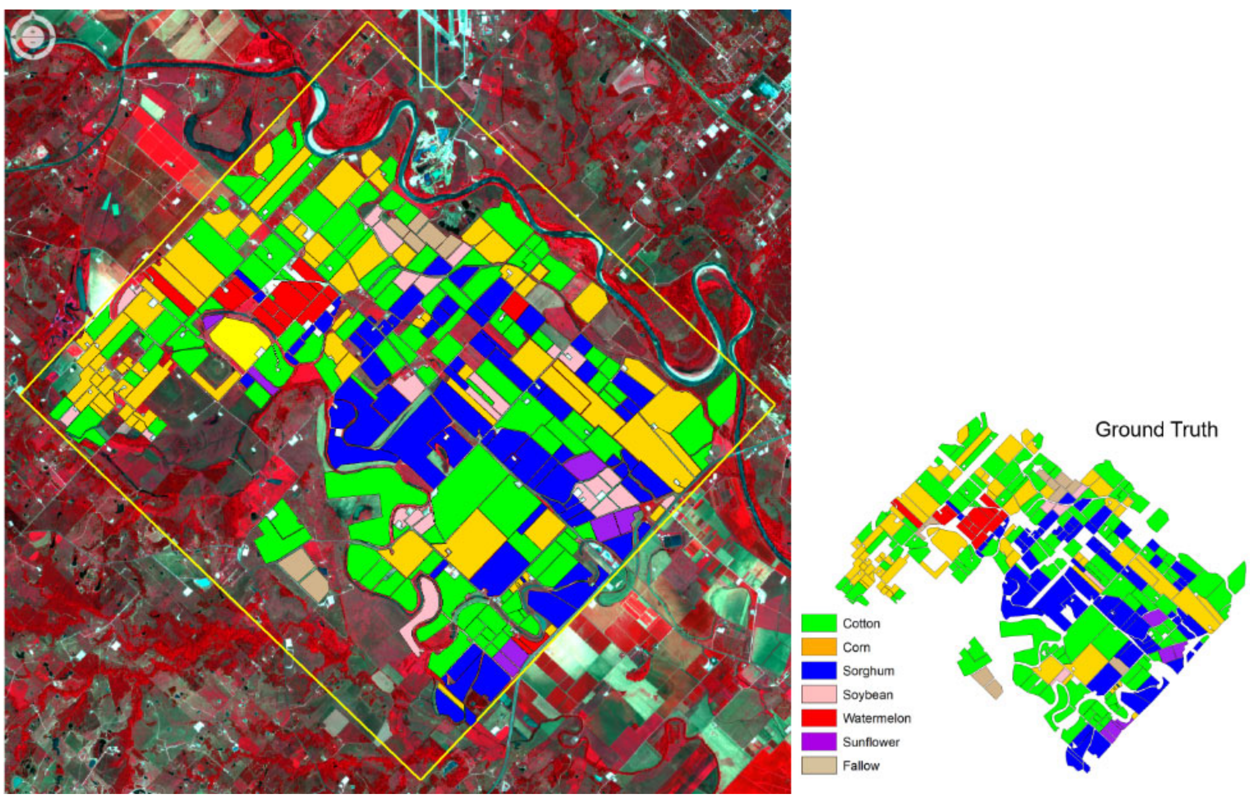

Figure 3. A filtered classification map for a Sentinel-2 image acquired on 10 June 2020 for a 10 km by 11 km area near Snook, TX.

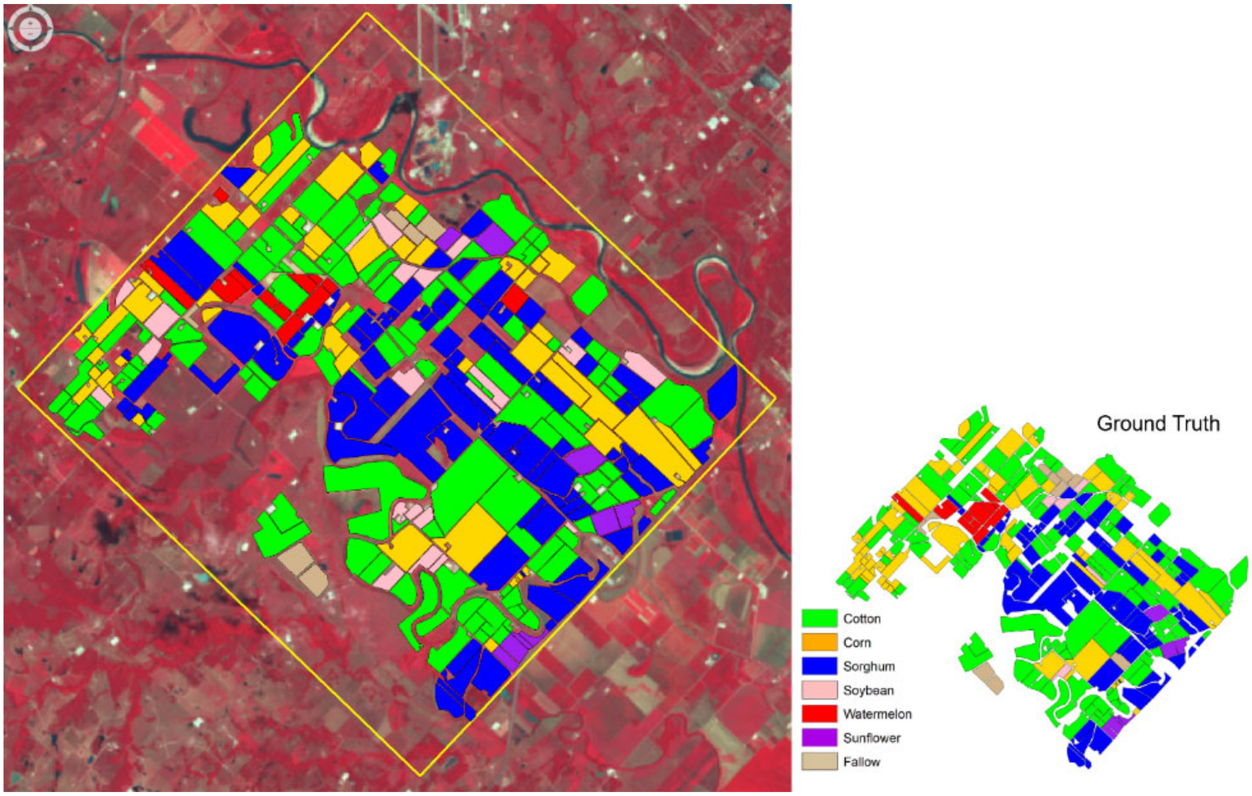

Figure 4. A filtered classification map for a Landsat 7 image acquired on 16 June 2020 for a 10 km by 11 km area near Snook, TX.

Table 1. Accuracy assessment results of classification maps for three types of images for identification of cotton fields in a cropping area near Snook, Texas, in 2020.

Image Type	Overall Accuracy For all Classes (%)	Producer's Accuracy For Cotton (%)	User's Accuracy For Cotton (%)
Airborne	83.2	87.6	87.4
Sentinel-2	89.7	84.5	95.8
Landsat 7	82.1	82.5	92.4

Summary

Preliminary results showed that Sentinel-2 and Landsat satellite imagery had similar performance to airborne imagery for crop identification, indicating that no-cost Sentinel-2 and Landsat imagery can be used for cotton field identification. The Sentinel-2 and Landsat 8 images collected in early May 2020 are being analyzed and evaluated for early identification of cotton fields. Efforts are also underway to evaluate advanced image classification techniques such as machine learning and deep learning classifiers for classification accuracy improvement.

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