IDENTIFICATION OF COTTON FIELDS USING SENTINEL-2 SATELLITE IMAGERY FOR BOLL WEEVIL ERADICATION

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Abstract

Early identification of cotton fields is important for advancing the boll weevil eradication program in Texas. Remote sensing has long been used for crop identification, but limited work has been reported on identification of cotton fields when cotton plants are small. Our previous work demonstrated that high-resolution airborne imagery was effective for this purpose, but large numbers of images taken along multiple flight lines are needed to cover large geographic regions. As 10-m Sentinel-2 satellite imagery is available at no cost and has large area coverage, this type of imagery was evaluated for identifying cotton fields before cotton plants start to bloom in this study. Three cloud-free scenes acquired on June 11, July 11, and August 15, 2019 were selected to identify cotton fields over a 10 km by 11 km cropping area. The images were classified into different crops and cover types using multiple supervised classification techniques. Preliminary results showed that Sentinel-2 imagery in conjunction with the maximum likelihood classifier was feasible for distinguishing cotton from other crops. However, the excessive rainfall in April and May delayed the planting of some cotton fields and the wet areas within crop fields affected the classification accuracy for the June 11 and July 11 scenes. Nevertheless, the methodologies presented in this study provide boll weevil eradication program managers with a tool to identify cotton fields over large geographic areas at relatively early growth stages.

Introduction

While the boll weevil (*Anthonomus grandis grandis* Boheman) has been eradicated from all cotton-producing states in the U.S. except for the Rio Grande Valley of Texas, cotton production areas adjacent to the lower Rio Grande Valley and Mexico remain susceptible to re-infestation due to migration or transport on harvesting equipment. In fact, boll weevils have been captured in the Uvalde and Kingsville areas in Texas since 2015. Early identification of cotton fields is critical for eradication program managers to effectively monitor boll weevil populations and treat the respective fields promptly. This information will also facilitate the quick detection of potential areas of volunteer and regrowth cotton on which weevil populations can survive and reproduce beyond the production season.

Yang et al. (2017) evaluated aerial imagery for identifying cotton fields before cotton started blooming and demonstrated that aerial images (1-m resolution) allowed for cotton field identification with an overall accuracy of more than 90%. However, aerial imagery provides a relatively small area of coverage compared to satellite imagery. Consequently, large numbers of aerial images taken along multiple flight lines with sufficient overlaps are required to cover large geographic areas. Image mosaicking techniques are then used to create a mosaic image of the area of interest. While aerial imagery is practical for small growing areas (e.g., less than 100 square miles), satellite imagery would be more practical for large regions, if proven effective. Imagery from satellite sensors such as Landsat has been used for crop identification and area estimation for decades (Oetter et al., 2000). Imagery from recently launched high-resolution satellite sensors has also been evaluated for crop identification (Turker and Ozdarici, 2011). However, limited information is available on the use of satellite imagery for early identification of cotton fields. The objective of this study was to determine whether 10-m Sentinel-2 satellite imagery could be used to identify cotton fields prior to bloom and at later stages.

Materials and Methods

Study Site

This study was conducted over a 10 km × 11 km cropping area with the center coordinates (30°34'7"N, 96°29'27"W) along the Brazos River near Snook, Burleson County, Texas (Figure 1). Cotton, corn, and grain sorghum are the main crops, with the majority of cotton acreage typically planted the first two weeks of April. Minor crops such as winter wheat, soybeans, and watermelon are also cultivated. In the 2019 growing season, cotton, corn and grain sorghum were the main crops, while some soybeans were also planted in the study area. All the fields were surveyed to determine crop types and all field boundaries were then digitized on Google Earth for accuracy assessment (Figure 1).

The total area of all the fields was 5094 ha and the areas for cotton, corn, sorghum, soybeans and fallow were 2553 ha (50.1%), 978 ha (19.2%), 516 ha (10.1%), 220 ha (4.3%) and 828 ha (16.2%), respectively.

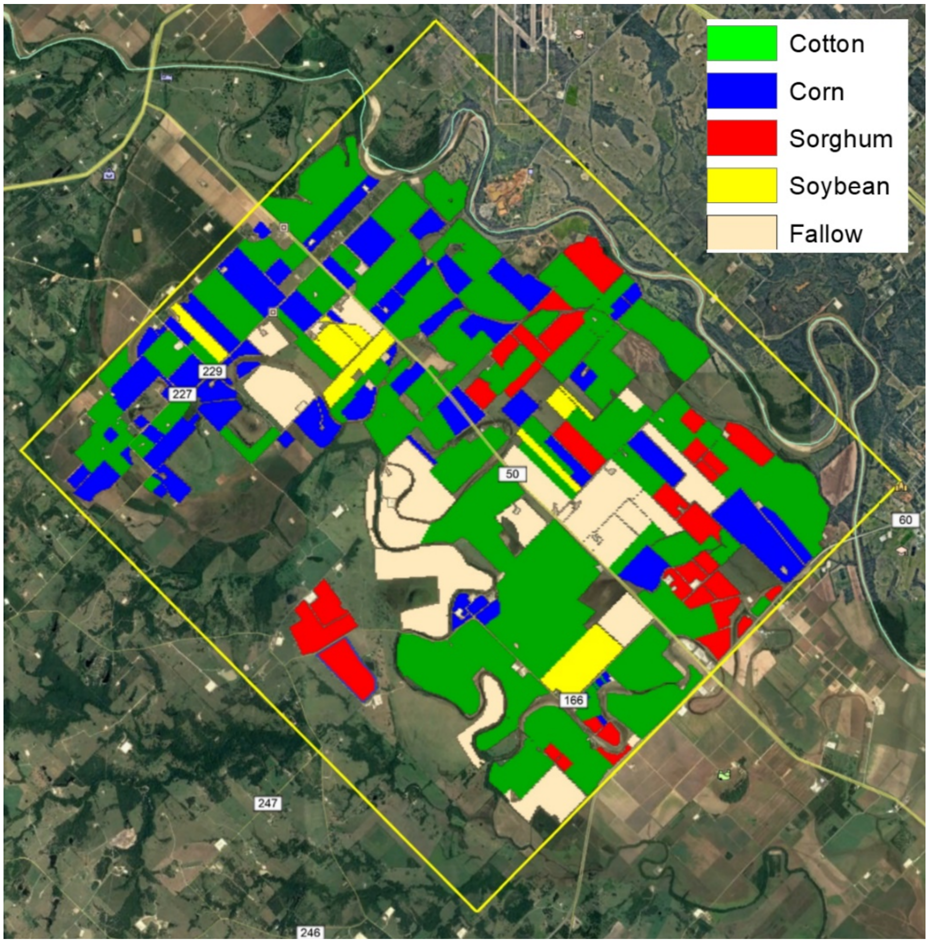

Figure 1. A 10 km by 11 km cropping area (yellow box) with color-coded crop types in 2019 overlaid on Google Earth map near College Station, TX.

Satellite Image Scenes

Three cloud-free Sentinel-2 scenes were acquired on June 11, July 11, and August 15, 2019. Each covered a ground area of 109.8 km by 109.8 km. The Sentinel-2 consists of two identical satellites, Sentinel-2A and Sentinel-2B, operated by the European Space Agency (ESA). Sentinel-2A and 2B each offer 13 spectral bands in the 443 to 2190 nm range with three visible bands (blue, green, red) and one near-infrared (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. All Sentinel-2 data products are provided free of charge to all users.

Figure 2 shows the color-infrared (CIR) composite image for June 11. At the time of image acquisition on June 11, cotton plants were predominately at the pinhead to the third-grown square stage with an average height of 20-50 cm and an average width of 22-55 cm in sampled fields. Because of excessive rainfall in April and May, cotton planting dates spanned from early April to mid-May. Fields planted in April had good canopy cover, while fields planted late looked like fallow fields. The dark areas on the CIR image indicated the flooded or wet areas in some of the fields.

Image Classification

As the boundaries for all the planted and non-planted fields in the study area were available, the major classes defined for image classification only included four crop types (cotton, corn, grain sorghum, and soybean) and one non-crop type (fallow). All other non-crop classes outside the fields were not considered. Due to the large variations within each of the five major classes, 2 to 11 subclasses within each major class were identified on the images, and varying numbers of training samples were extracted from the images to create the signatures for a total of 25 subclasses. One signature file was created for each image and each file contained 25 signatures to represent the respective subclasses.

Figure 2. Color-infrared composite image acquired on June 11, 2019 for a study area near College Station, TX.

Five supervised classifiers built in Erdas Imagine (Intergraph Corporation, 2013), including maximum likelihood, minimum distance, Mahalanobis distance, spectral angle mapper (SAM), and spectral correlation mapper (SCM), were applied to the three images. Thus, a total of 15 classification maps were generated. The 25 subclasses in each map were then merged into the five major classes. Because of within-field variability and spectral similarity between the classes, multiple classes coexisted within the same field on all classification maps. To make sure that each field contained only one class, all the pixels within the field were reassigned to the majority class.

Accuracy Assessment

For accuracy assessment, each 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

Figures 3 and 4 show the original classification map and the filtered classification map with pixel reassignment, respectively, based on the maximum likelihood for the June 11 image. A quick comparison of the classification maps with the ground survey map shown in Figure 1 indicates that the classification maps correctly identified most of the cotton fields. However, a number of cotton fields were misclassified as fallow due to the spectral similarity in the areas with small plants and wet soil background. Misclassifications also occurred among the other classes, particularly when plants were small.

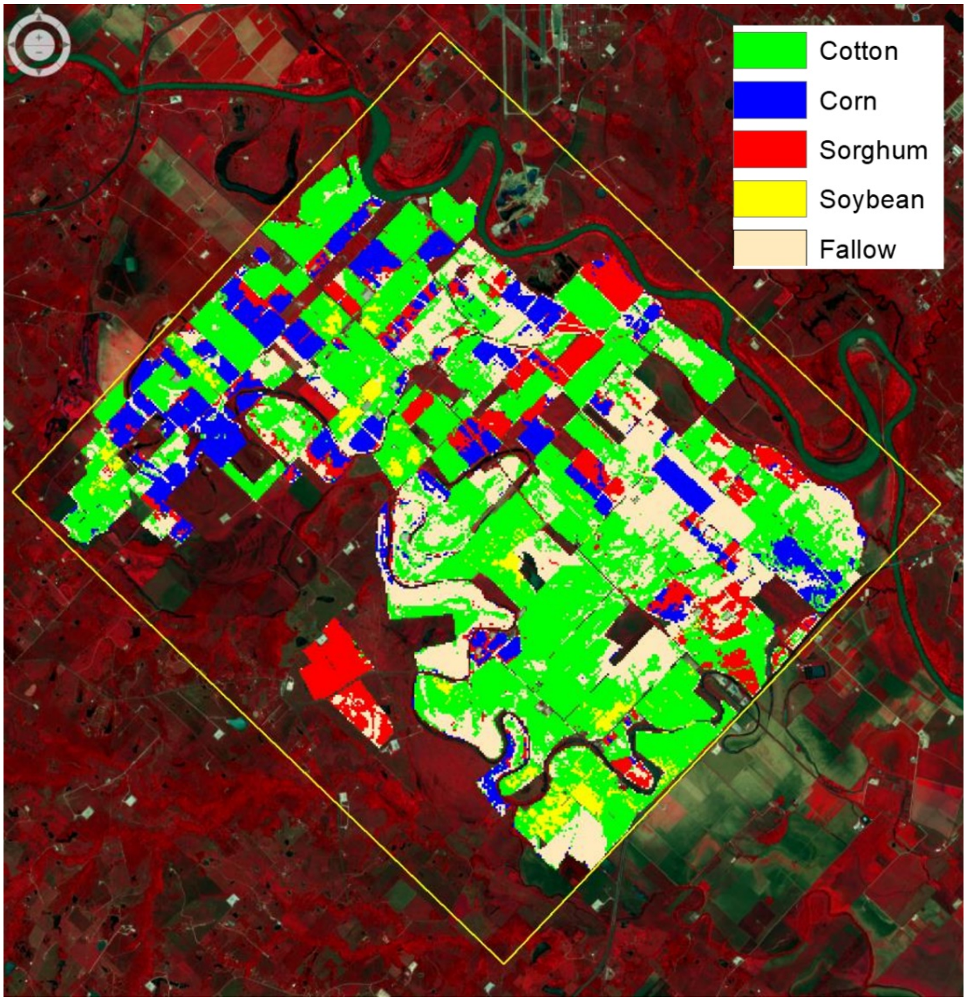

Figure 3. A classification map based on the maximum likelihood classifier for a Sentinel-2 image acquired on June 11, 2019 for a study area near College Station, TX.

Table 1 shows the accuracy assessment result for the filtered classification map. The overall accuracy of the classification map was 74.2%, indicating that approximately three quarters of the image pixels were correctly identified in the classification map. 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. The producer's accuracy (a measure of omission error), which indicates the probability of actual areas being correctly classified, was 76.4% for the cotton category. The user's accuracy (a measure of commission error), which is indicative of the probability that a category on the map actually represents that category on the ground, was 79.8% for cotton. Corn and sorghum had higher producer’s and user’s accuracy values than cotton, but there were some misclassifications with other classes. Soybeans had the lowest accuracy values among all the classes because the crop was mainly misclassified as cotton. Fallow also had low accuracy values primarily due to its confusion with late planted cotton.

Accuracy assessment results for the maximum likelihood-based classification maps for the other two images showed that overall accuracy was only 73.5% for July 11 and 90.3% for August 15. By July 11, all crops had full canopy cover, though wet areas could still be seen in some fields. In addition, the grass in the fallow fields were green and healthy. As a result, some cotton areas were misclassified with the other crops and fallow areas. The producer's and user's accuracy values for cotton were 88% and 74%, respectively on July 11. By August 15, corn was senesced or harvested and sorghum reached its maturity, while cotton was still vegetative and lush. Cotton had the highest accuracy values with a producer's accuracy of 93% and a producer's accuracy of 96%.

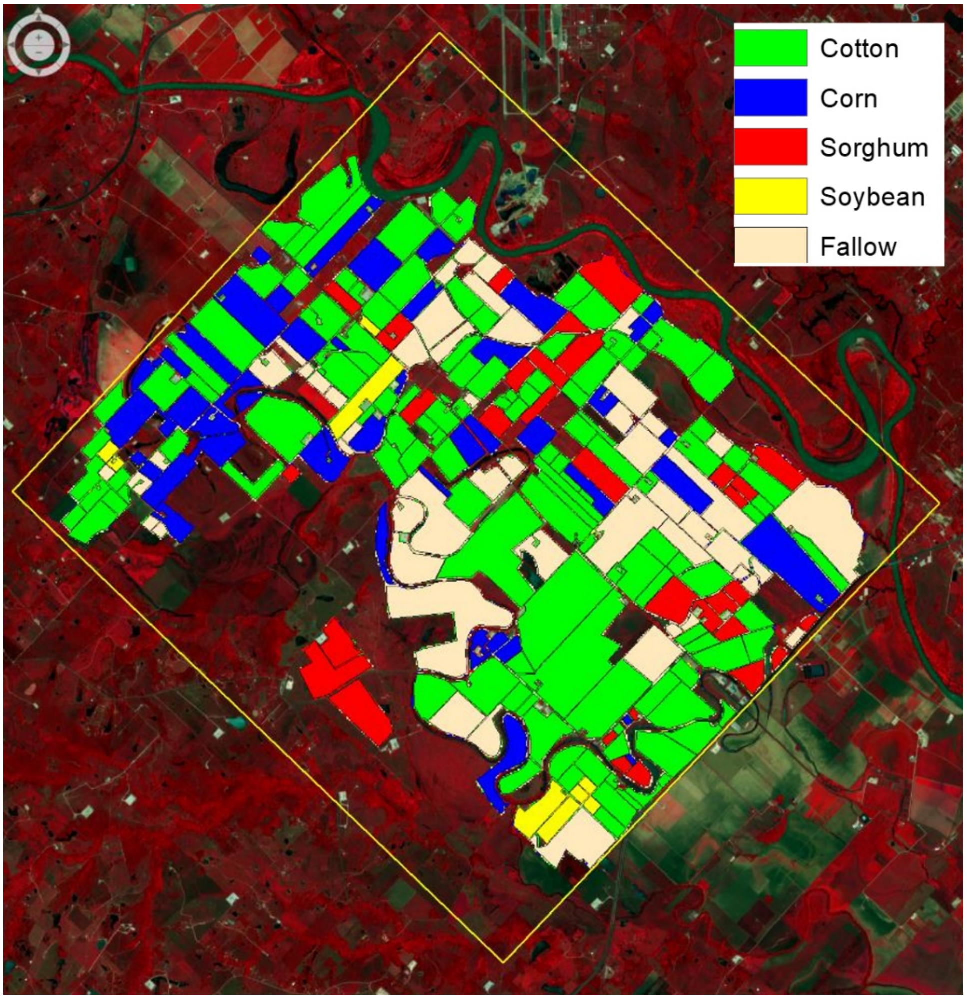

Figure 4. A filtered classification map after the pixels within each field in the classification map shown in Figure 3 were reassigned to the dominant crop class.

Table 1. Accuracy assessment result for a two-zone classification map of a normal color image for identification of cotton fields in a cropping area near College Station, TX, in 2019.

Classified Category	Actual Category (m^2)					Total	User's Accuracy
	Cotton	Corn	Sorghum	Soybean	Fallow		
Cotton	19505316	716035	371501	1802067	2034275	24429194	79.8%
Corn	43979	7972568	0	0	511365	8527912	93.5%
Sorghum	83680	861853	4172505	0	0	5118038	81.5%
Soybean	674085	0	90574	395202	0	1159861	34.1%
Fallow	5227333	229142	521126	0	5730896	11708497	48.9%
Total	25534393	9779598	5155706	2197269	8276536	37776487	
Producer's Accuracy	76.4%	81.5%	80.9%	18.0%	69.2%		

Overall accuracy = 74.2%. Kappa = 0.619. Total Area = 5094 ha.

Summary

Preliminary results from this study showed that Sentinel-2 imagery is promising for cotton field identification at relatively early growth stages. Excessive rainfall and different planting dates in 2019 made it difficult to distinguish some cotton fields from other crops and fallow. More research is needed to compare airborne imagery (< 1 m) and low-cost/no-cost satellite imagery (5-30 m) for identification of cotton fields during the growing season.

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References

Intergraph Corporation. 2013. ERDAS Field Guide. Intergraph Corporation, Huntsville, AL.

Oetter, D.R., W.B. Cohen, M. Berterretche, T.K. Maiersperger, and R.E. Kennedy. 2000. Land cover mapping in an agricultural setting using multiseasonal Thematic Mapper data. Remote Sensing of Environment 76: 139-155.

Turker, M., and A. Ozdarici. 2011. Field-based crop classification using SPOT4, SPOT5, IKONOS and QuickBird imagery for agricultural areas: a comparison study. International Journal of Remote Sensing 32(24): 9735-9768.

Yang, C., J.H. Everitt, and D. Murden. 2011. Using high resolution SPOT 5 multispectral imagery for crop identification. Computers and Electronics in Agriculture 75: 347-354.

Yang, C., C.P.-C. Suh, and J.K. Westbrook. 2017. Early identification of cotton fields using mosaicked aerial multispectral imagery. Journal of Applied Remote Sensing 11(1), 016008.