DETECTING PLASTIC TRASH IN A COTTON FIELD WITH A UAV

Robert G. Hardin IV
USDA-ARS Cotton Ginning Research Unit
Stoneville, MS
Yanbo Huang
Ryan Poe
USDA-ARS Crop Production Systems Research Unit
Stoneville, MS

Abstract

Plastic contamination is a major concern for the US cotton industry. A significant proportion of plastic entering a cotton gin will remain in the fiber, potentially contaminating yarn or fabric, resulting in economic losses through claims on rejected material, loss of market share, and damage to the industry's reputation. One source of plastic that can enter the processing stream regardless of industry management practices is improperly disposed trash, commonly found in fields near roads. After defoliation, color and near-infrared images) of a cotton field bordering a road were obtained with an unmanned aerial vehicle (UAV). Trash in the field was collected and the location and description recorded just prior to harvest. The spectral reflectance of the trash and background objects from the field was measured to identify additional wavelengths that could be used to classify field trash. Sixteen pieces of trash were found in the field near the 315 m border with the road, 14 were plastic. Individual items could be identified in the RGB images, but the spatial resolution of the color-infrared image was too low. Reflectance data collected in the laboratory identified wavelengths that could be used for trash classification. Imagery will be collected from additional fields in 2018 at a lower altitude to improve resolution so that algorithms for classifying trash can be developed.

Introduction

Although US cotton is among the least contaminated in the world, recent surveys indicate that the incidence of plastic contamination is increasing (International Textile Manufacturers Federation 2014). The increasing prevalence of contamination detection systems in textile mills has also highlighted this problem. Cleaning machines in cotton gins (Byler, Boykin and Hardin 2013, Hardin and Byler 2016) and textile mills (van der Sluijs and Freijah 2016) do not remove all plastic contamination, resulting in contamination of finished goods. The cost of contamination claims to the US cotton industry has been estimated at over $100 million. Sources of plastic contamination in the field can be categorized into two groups:

- Plastic used in agricultural operations, including irrigation pipe, plastic mulch, and module wrap. This material may be located throughout the field, and best management practices can reduce or eliminate this contamination source.
- Plastic trash that has been improperly disposed, such as shopping bags, food and drink containers, and plastic wrappers. Cotton producers have little control over the presence of this material in their fields; however, trash will generally be found near roads.

If these plastic trash items are collected with cotton during harvest, they may be particularly difficult to remove with existing gin and mill cleaning equipment, because much of this plastic is thin, and field weathering may have degraded the material into small pieces (Hardin and Byler 2016, Byler, Boykin and Hardin 2013). Therefore, removing trash along roadsides prior to cotton harvest may be justified, depending on the amount and type of plastic and the cost of removal. Remote sensing has been used to identify agricultural plastic in the environment, for example, greenhouses, row covers, and mulches (Levin, et al. 2007, Picuno, Tortora and Capobianco 2011, Tarantino and Figorito 2012). However, these studies were typically conducted using satellite imagery with a spatial resolution too low to identify small pieces of plastic trash. While trash items could be identified based on size and shape, laboratory testing has also demonstrated the ability to discriminate cotton and field trash using NIR spectroscopy (Fortier, et al. 2012).

The increasing adoption of unmanned aerial vehicles (UAV's) in agriculture provides a potential solution to the problem of trash identification and location. A UAV can collect high-resolution imagery (visible and infrared) of cotton fields prior to harvest. The goal of this work was to explore the feasibility of using images collected by a UAV to identify contaminants in a cotton field. This research should lead to the development of image analysis software to automate the identification of contaminants, which could be used to direct a field robot for automated removal. Specific objectives of this work were:

- Image a cotton field with a UAV-based multispectral camera to determine the feasibility of identifying trash.
- Manually quantify the amount and type of trash found in the cotton field.
- Measure hyperspectral reflectance from the collected material in the laboratory to identify potential wavelengths for field identification.

Materials and Methods

Site Description

The cotton field selected for this study was approximately 8 ha (20 ac) and located immediately south of the USDA-ARS Cotton Ginning Research Unit (Figure 1). The east side of the field is 315 m (1030 ft) long and borders a road. While not a major highway, the road is moderately traveled due to the traffic to the experiment station and use as a secondary route headed north or west from a nearby town. This field was defoliated initially on 18 September 2017 and again on 26 September. Aerial images were collected on 21 and 26 September and 2 October. After the final image was collected and just prior to harvest beginning later that day, trash in the field was manually collected and the location and description recorded.

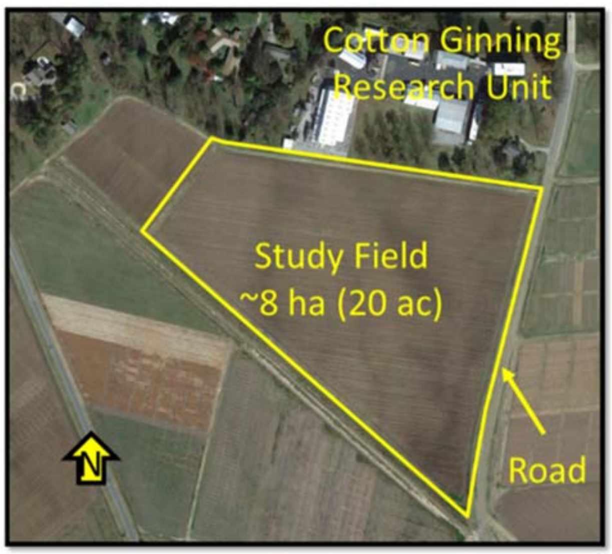

Figure 1. Field used in the study.

Aerial Imaging

Images of the cotton field were acquired with a Parrot Sequoia multispectral camera (MicaSense, Seattle, WA) using a DJI Phantom 3 Advanced UAV (DJI, Shenzhen, China). The Sequoia camera has four narrow spectral bands of green, red, red edge and near infrared (NIR) at 550, 660, 735 and 790 nm respectively. This camera also concurrently acquires 16 megapixel broad-band RGB images. With the UAV flight altitude at 50 m and a 70.6^{o} angle of view, the RGB images had a spatial resolution of 6 cm per pixel, while the color-infrared (CIR) images had 22 cm per pixel. This Sequoia camera is integrated with a sunshine sensor, allowing the imaging system to be used in either clear or overcast weather conditions with real-time sensor calibration.

Spectral Reflectance

Spectral reflectance of the trash collected in the field, as well as a cotton ball, cotton calyx, and soil from the field, was measured with a Fieldspec 3 spectroradiometer (ASD Inc., Boulder, CO), which has an attached sample contact probe and a spectral range of 350 to 2500 nm. The contact probe has its own light source allowing data collection in all lighting conditions. Five reflectance measurements were collected on each sample. Each measurement was an internal average of fifteen readings by the spectroradiometer. The spectroadiometer was calibrated with a white spectralon panel.

Results and Discussion

Along the road, 16 items were found in the cotton field (Figure 2). A brief inspection of other areas of the field did not reveal any trash; however, an extensive search was not conducted. The items found included multiple polystyrene foam food and drink containers (6); polyethylene films, such as shopping bags (1), storage bags (1), and trash bags (1); plastic wrappers from packaging, likely polypropylene (2); a polyethylene terephthalate (PET) bottle (1); plastic pipe (1); plastic tape (1); foil (1); and paper (1).

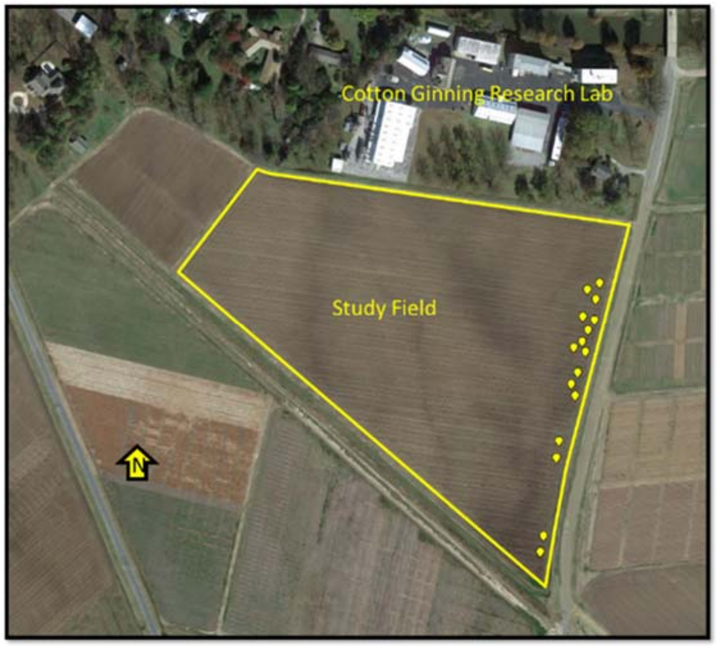

Figure 2. Trash locations in the field.

Trash was manually identified in the RGB images collected on 26 September. The following examples show a shopping bag (Figure 3) and a polystyrene foam cup (Figure 4) in the field. Spatial resolution of the CIR (22 cm) was too large to easily visually identify trash.


Figure 3. Aerial image of shopping bag in field.

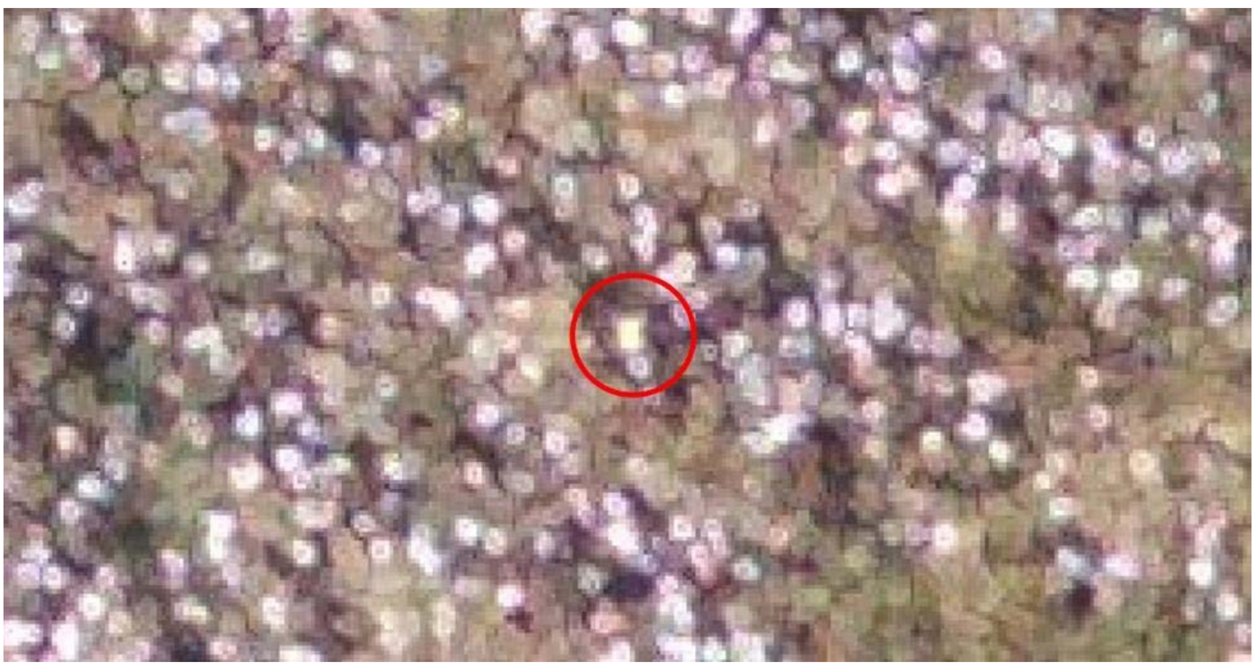
Figure 4. Aerial image of polystyrene foam cup in field.

The spectral reflectance data from the trash collected in the laboratory indicated additional possibilities for identifying plastic trash in the cotton field. The polystyrene materials have a sharp decrease in reflectance at around 1680 nm that was not present in the background objects (Figure 5). Reflectance of the polystyrene materials was also high and generally constant throughout the visible and near-infrared wavelengths.

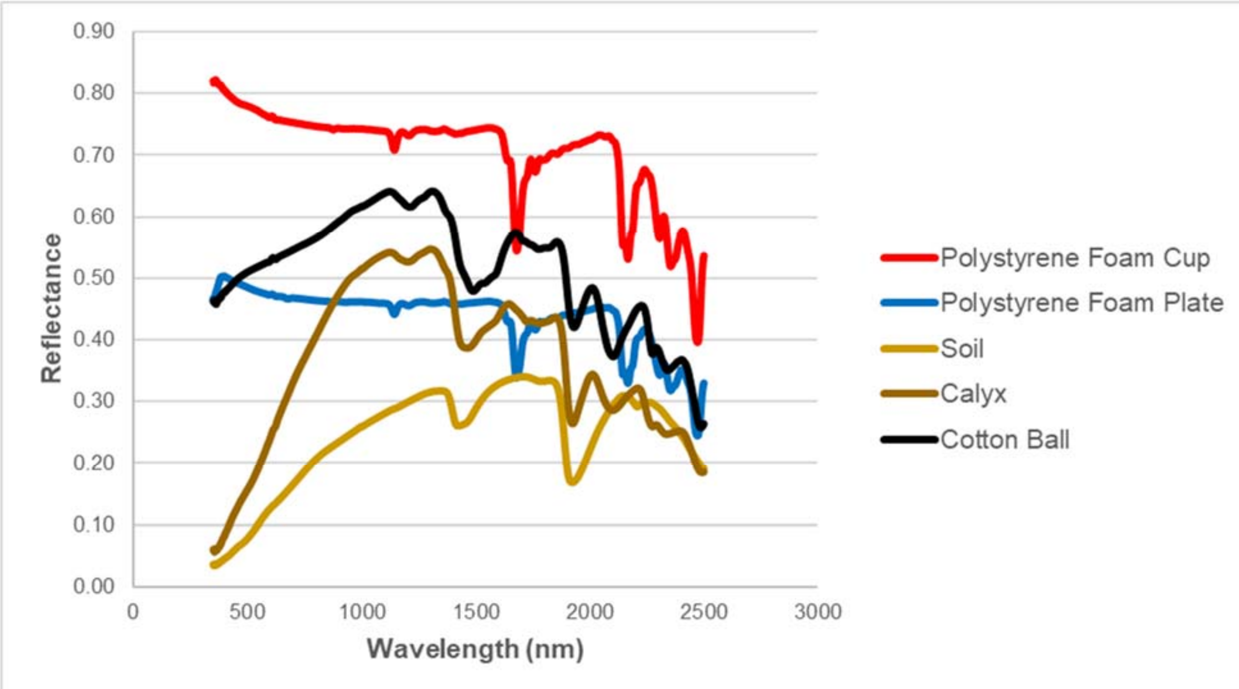

Figure 5. Reflectance of polystyrene and background objects.

The polyolefin materials (polyethylene and polypropylene) exhibit peaks at around 440 nm and a distinct decrease at around 1730 nm (Figure 6). Also, reflectance generally decreases throughout the visible and near-infrared range.

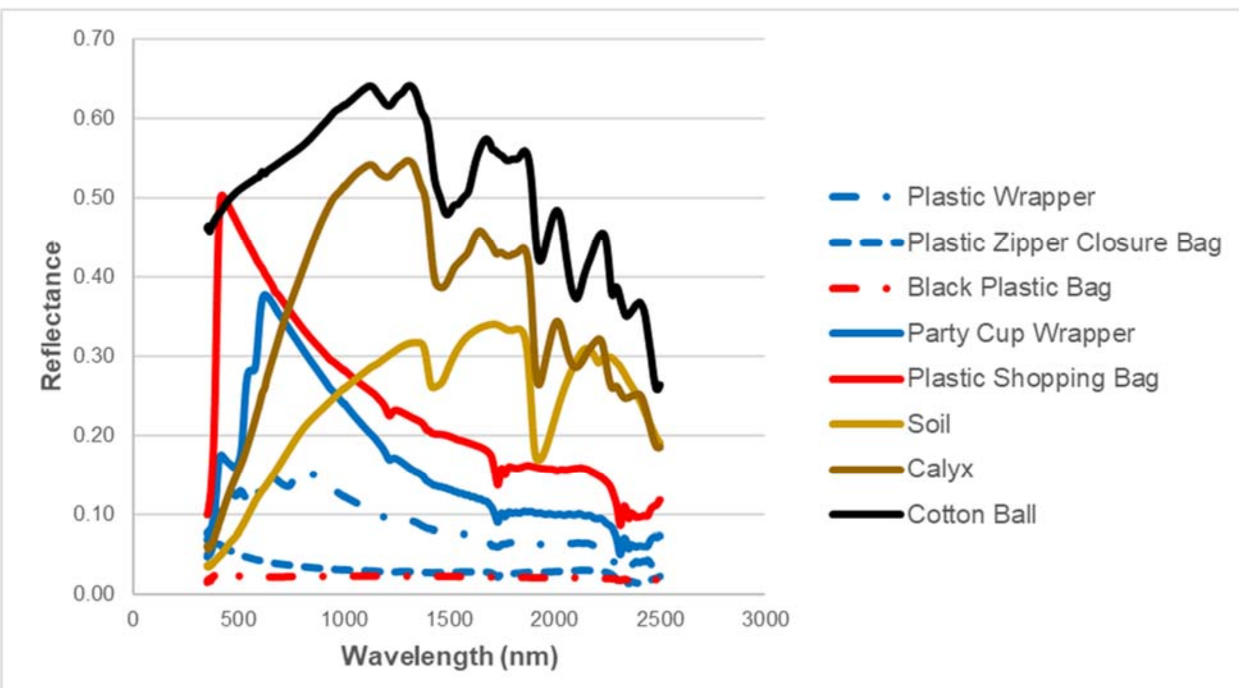

Figure 6. Reflectance of polyolefin and background objects.

Future Work

Results of this initial investigation have highlighted the potential of using images collected from a UAV to identify plastic contamination in the field. This work will be continued in 2018, with multiple fields imaged. UAV's will be flown at a lower altitude, likely 10-20 m (33-66 ft) to collect higher resolution imagery. Classification algorithms will be developed, based on reflectance values, as well as the size and shape of detected objects. While trash objects are visible in the RGB images, imaging at longer wavelengths, such as 1680 and 1730 nm, or at ultraviolet wavelengths, may improve classification accuracy.

Once successful classification algorithms are developed, the location and, possibly, a description of trash items could be delivered to the cotton producer via an application on a phone or tablet. Long-term solutions to address this problem may include field robots to collect plastic trash. UAV-collected imagery may be the most efficient means to direct these field robots.

Conclusions

Sixteen pieces of trash were collected from the edge of a cotton field that had a 315 m (1030 ft) border with a road. Nearly all the trash collected (14/16 objects) was plastic. This field trash was identified in RGB images collected from a UAV; however, the spatial resolution of the CIR images was too low to manually identify trash. Spectral reflectance data collected in the laboratory indicated additional wavelengths, primarily in the infrared region, that could assist in identifying plastic field trash. Additional images will be collected in 2018, at higher spatial resolutions and possibly additional wavelengths.

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Disclaimer

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