EVALUATION OF RELATIONSHIP BETWEEN HVI ESTIMATED LEAF GRADE AND MDTA3 MEASURED PERCENT TRASH

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Abstract

The main question under consideration for this manuscript was "Can leaf grade be used to reliably predict the mass of trash in a bale of cotton fibers?" Data from lint samples collected during the 2005 ginning season from 11 different gins across the Cotton Belt were used for this evaluation. HVI® and MDTA3 measurements were made for 470 cotton samples. Then, instrument leaf grades were assigned based on HVI percent area and trash count. Analyses were conducted to examine the relationship between the HVI estimated leaf grade and percent trash by mass determined from the MDTA3. There was a weak relationship between trash content and leaf grade. A loose interpretation of the data showed that the average trash contents for leaf grades 1, 2, 3, and 4 were roughly 1, 2, 3, and 4% by mass, respectively, but the actual trash content could likely vary from those estimates by ±100% of the average. More precisely, HVI leaf grade was a poor predictor of trash content as illustrated by the low adjusted R^2 = 0.572. A relationship developed from three HVI measurements (trash percent area, trash count, and color grade) resulted in a slightly better prediction of trash content (adjusted R^2 = 0.653). Additional data points and inclusion of other HVI measurements, as well as AFIS measurements, may improve estimation of the mass trash in a bale of cotton in the future. In the end, HVI trash and color measurements are based on two-dimensional images of the surface of a cotton sample and do not provide information about trash thickness or density or content within the sample and thus, may not be representative of the total mass of trash in that sample.

Introduction

In 2012, the USDA Agricultural Marketing Service (AMS) transitioned from manually assigned cotton leaf grades based on human judgement to instrument leaf grades based on High Volume Instrument (HVI®, Uster Technologies, Charlotte, NC) measurements (AMS, 2012) Leaf grade is an indicator of the leaf content in the cotton, which is waste to the mill (Cotton Inc., 2013). There is interest in understanding the relationship between leaf grade and trash content by mass in cotton. The main question under consideration for this manuscript was "*Can leaf grade be used to reliably predict the mass of trash in a bale of cotton fiber?"*

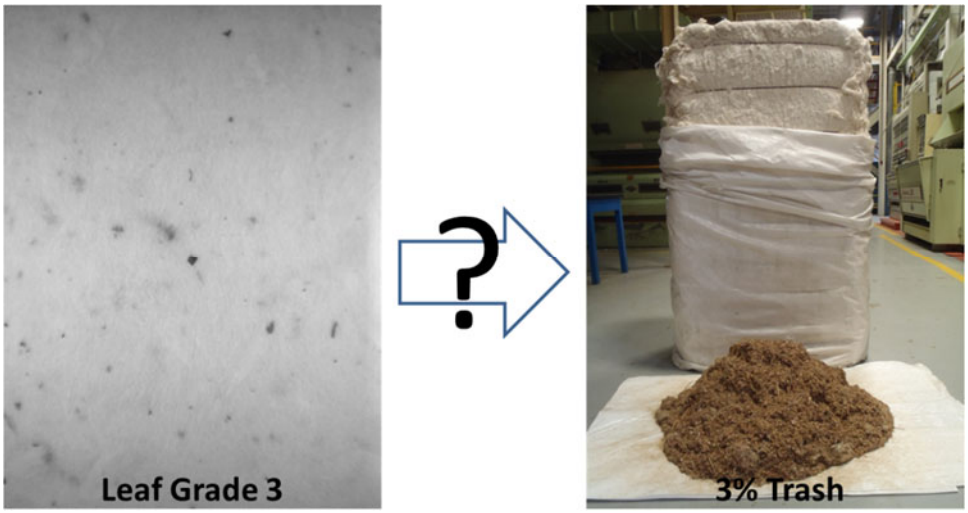

Figure 1. Can HVI leaf grade be used to predict the mass of trash in a cotton bale?

Materials and Methods

A subset of samples collected for a previous study by Whitelock et al. (2011) during the 2005 ginning season from 11 different gins across the Cotton Belt were used for this evaluation. In the 2005 study, HVI and Micro Dust and Trash Analyzer III (MDTA3, Uster Technologies, Charlotte, NC) measurements were made at Cotton Incorporated. The HVI utilizes digital images of the cotton sample to determine the number of trash particles (trash count) and the fraction of the cotton surface covered by the trash particles (percent area). The MDTA3 employs mechanical and pneumatic principles to separate foreign matter or trash from a known mass of cotton lint for subsequent weighing and calculation of percentage of original sample mass. HVI percent area and trash count data from 470 samples were provided in 2015 to the USDA AMS that then assigned an instrument leaf grade for each sample. Analysis was conducted to examine the relationship between the HVI estimated leaf grade and percent trash by mass determined from the MDTA3.

Results

Figure 2 shows a histogram of number of samples per leaf grade level. Note that there were relatively few samples for leaf grades 6 and higher in the data set.

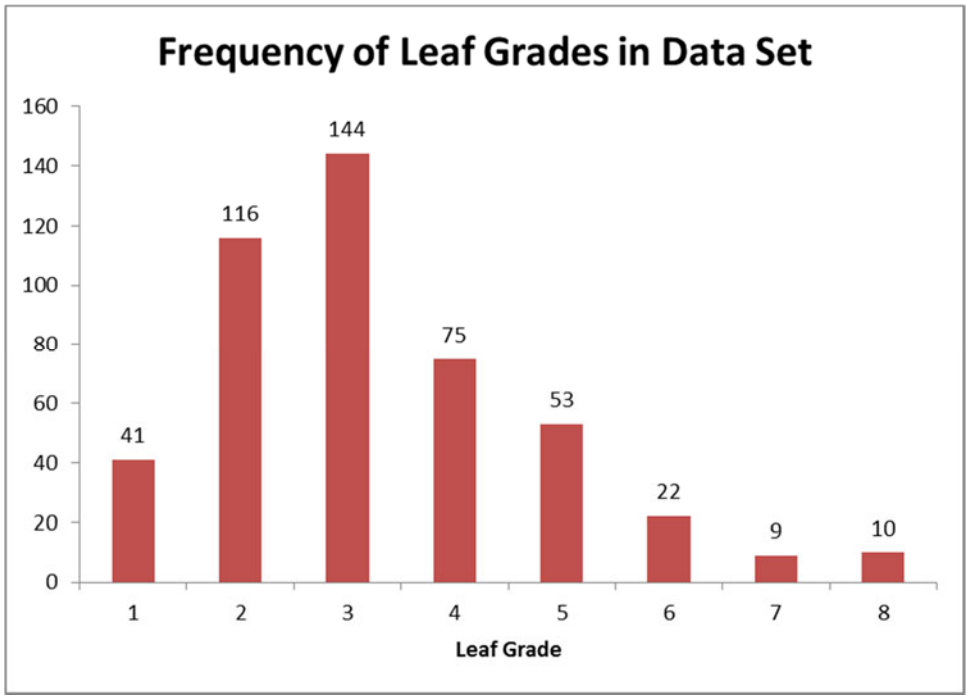

Figure 2. Histogram of samples per leaf grade level.

Analysis of variance of MDTA3 trash content showed that there were significant differences among HVI leaf grades (Figure 3). However, the differences were not significant among leaf grades 5, 6, and 7. Also, there was considerable variability in the trash content for a particular leaf grade, as illustrated by the vertical spread of points in Figure 3 and large standard deviations. For the lower leaf grades 1, 2, 3, and 4, the average trash content could be roughly approximated at 1, 2, 3, and 4% by mass, respectively. However, due to variability in the data, the actual trash content could likely vary from those estimates by ±100% of the average value (2×SD).

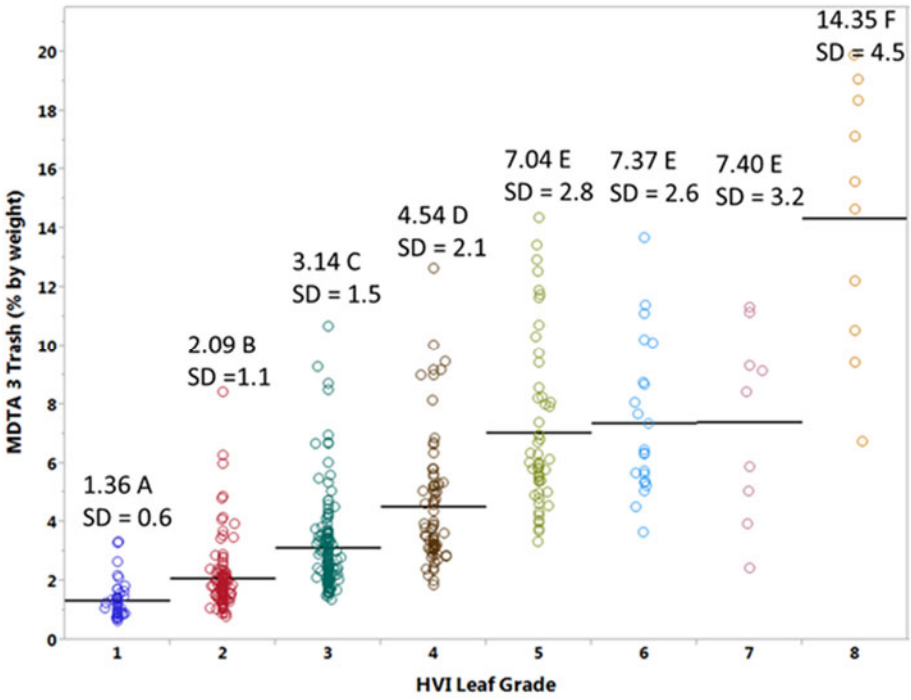

Figure 3 – MDTA3 trash content for HVI leaf grades. Means shown for each leaf grade followed by different letters are significantly different ($\alpha = 0.05$).

Regression analysis of MDTA3 trash content against leaf grade resulted in the following equation:

$$y = -1.015 + 1.497 * \text{leaf grade} \qquad (1)$$

with adjusted $R^2 = 0.572$, root mean square error (RMSE) = 2.00 and predicted residual sum of squares (PRESS) statistic = 1904. These statistics and Figure 4 show that leaf grade does not predict trash content particularly well with a single value of trash content predicted for a relatively wide range of corresponding actual trash content values. One issue with this approach is that leaf grade is actually a grade or level that could be represented by categorical factors, such as A – H, as opposed to a continuous factor.

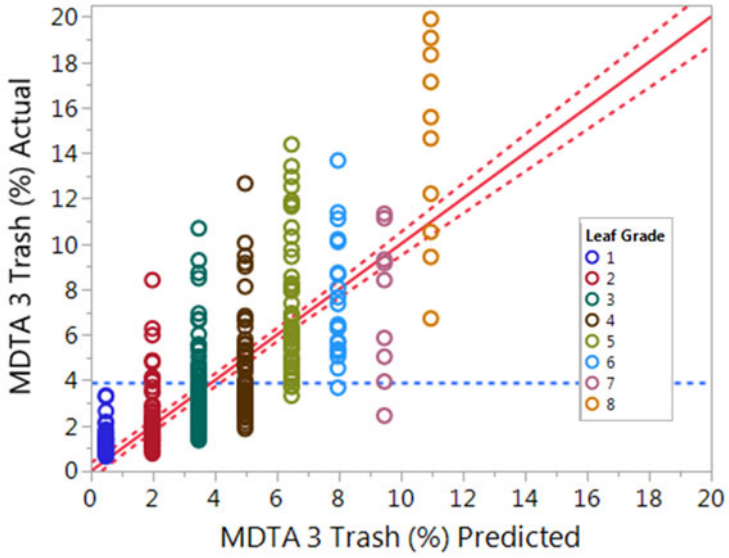

Figure 4. Actual versus predicted MDTA3 trash content from regression analysis with HVI leaf grade (Equation 1).

HVI leaf grade is determined based on the HVI measurements of trash percent area and trash count. Figure 5 shows HVI area versus HVI trash count with leaf grade indicated by color. The figure shows that there is a strong correlation between percent area and trash count.

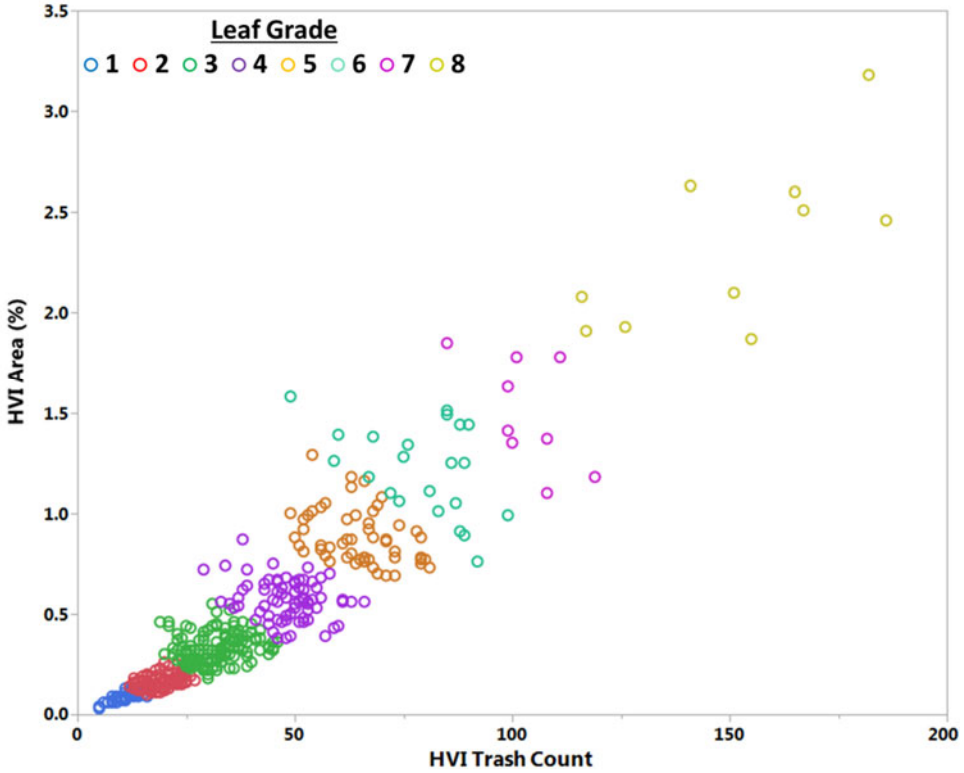

Figure 5. HVI percent area versus HVI trash content with corresponding leaf grades indicated by color.

Regression of MDTA3 trash content against HVI trash percent area and trash count showed that prediction of trash content with percent area was only slightly better than with leaf grade (Figure 6). The resulting fit statistics were adjusted R^2 = 0.584, RMSE = 1.97 and PRESS = 1850. When HVI trash count was used as the regressor, the prediction of trash content was better with adjusted R^2 = 0.650, RMSE = 1.81 and PRESS = 1553.

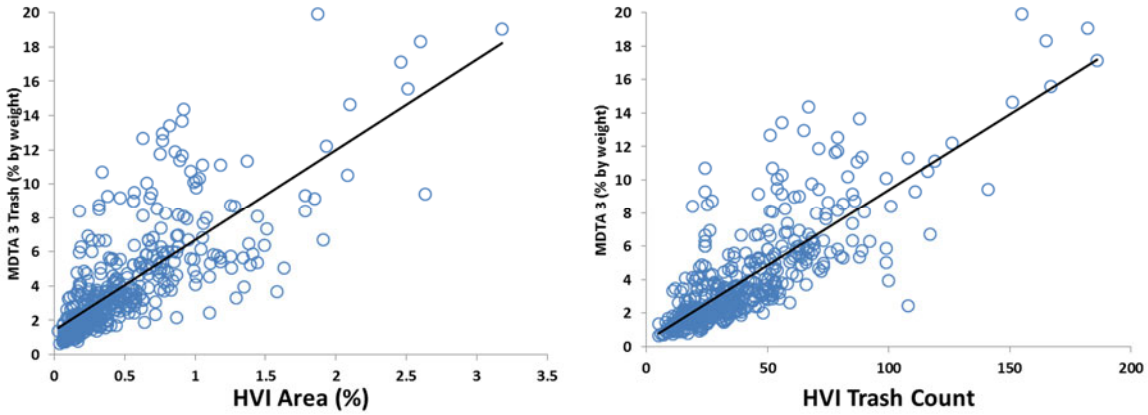

Figure 6. MDTA3 trash content versus HVI percent area and trash content with line-of-fit.

There are several HVI measurements than could be significantly affected by trash content – leaf grade, trash percent area and count, and color Rd, +b, and grade (Figure 7). Correlation analyses showed that leaf grade, trash area, and trash count had the most significant correlations with MDTA3 trash count (coefficients of correlation greater than

0.75). Color Rd and color grade were somewhat correlated with trash content with correlation coefficient of about -0.50. Color grade in this case was converted to a coded continuous variable where HVI color grade 11 = 105, 21 = 104, 12 = 103, etc.

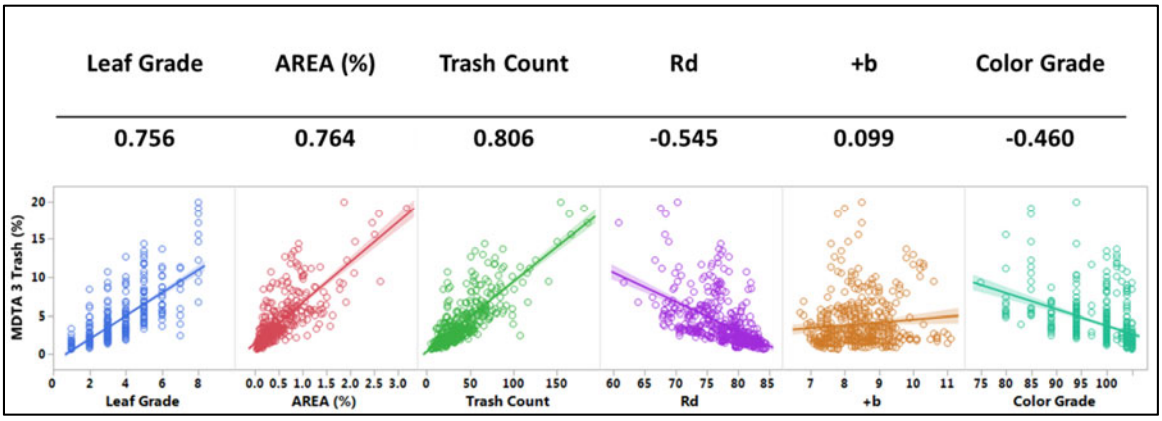

Figure 7. Correlation of HVI leaf grade, trash percent area, trash count, and color Rd, color +b, and coded color grade with MDTA3 trash content.

A multiple regression analysis resulted in three of the HVI measurements as significant factors for predicting trash content – trash percent area, trash count, and coded color grade.

$$y = -9.541 + 1.339 * \text{area} + 0.085 * \text{count} + 0.095 * \text{color grade} \qquad (2)$$

The model was only slightly better than using HVI trash count alone with fit statistics adjusted $R^2 = 0.653$, RMSE = 1.77 and PRESS = 1479. Also, there was considerable scatter revealed in the actual versus predicted plot (Figure 8).

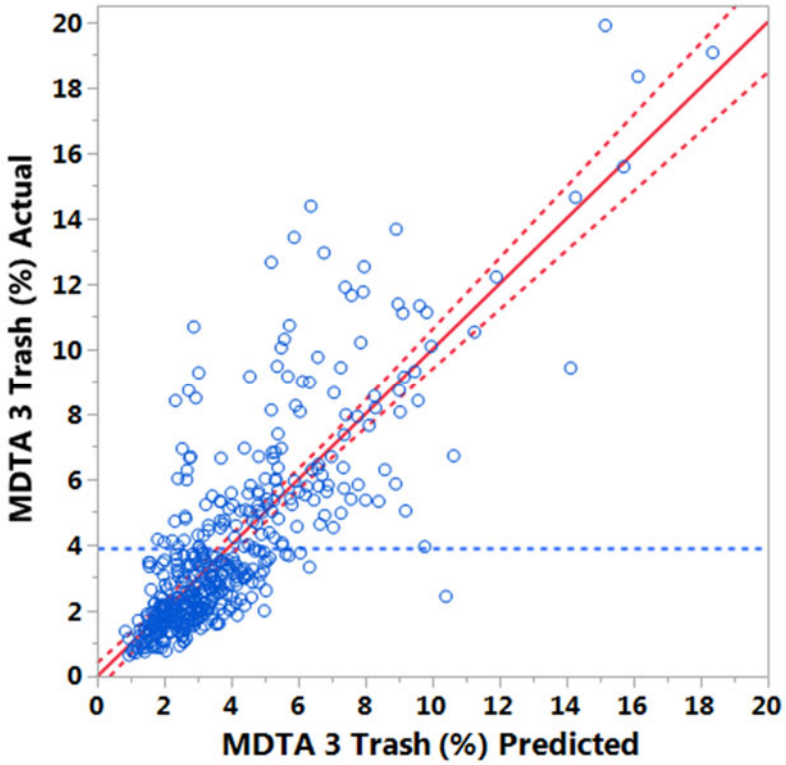

Figure 8. Actual versus predicted MDTA3 trash content from multiple regression analysis with HVI percent area, trash count and coded color grade (Equation 2).

Summary

The question whether HVI leaf grade can be used to reliably predict the mass of trash in a bale of cotton fibers was explored. The results showed a weak relationship between trash content and leaf grade. Thus, leaf grade was a poor predictor of trash content. Two specific reasons for this were that leaf grade is a categorical factor and there was wide variation in trash content for each leaf grade. Utilizing a combination of HVI measurements resulted in only a slightly better prediction of trash content than using leaf grade alone.

Various reasons could explain for the poor relationship between HVI measurements and MDTA3 trash content. HVI trash and color measurements are based on two-dimensional images of the surface of the cotton samples and are not capable of providing information about trash thickness, density, or mass. MDTA3 is a physical separation process that thoroughly accounts for all non-lint materials, but uses only a 5 gram sample for the analysis. Thus, it may not always be representative of the larger HVI sample or associated cotton bale. These factors likely add variance to the relationship between HVI leaf grade or other measurements and MDTA3 trash content. Another consideration is that the number of data points in the higher leaf grades was low. Additional data may improve prediction. Other HVI measurements, as well as AFIS measurements, may also give a better estimation of trash content.

Keeping in mind there is considerable scatter in the relationship, a loose interpretation of the data showed that the relationship between percent mass of trash and leaf grade was roughly one-to-one. Trash contents for leaf grades 1, 2, 3, and 4 were approximately 1, 2, 3, and 4% by mass, respectively. However, due to variability in the data, the actual trash content could likely vary from those estimates by ±100% of the average value. Also, this linear relationship may not be an appropriate estimate for higher leaf grades, but the limited number of samples for leaf grades 6 and higher in this data set was not sufficient to be conclusive.

Disclaimer

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