RELATIONSHIP BETWEEN THREE COTTON TRASH MEASUREMENTS: HVI, SA, AND AFIS

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Abstract

Presence of non-lint materials (trashes) in commercial cotton bales at various amounts degrades the market values and further influences the end-use qualities. In order to ensure a fair trading, the USDA's AMS has introduced the high volume instrument (HVI) measurement as a universal standard index. Trash contents are generated by one of three HVI modules and represent the trash portion only detectable on samples' surfaces. In additional to HVI's geometric method, gravimetric-based Shirley analyzer (SA) and advanced fiber information system (AFIS) have also been utilized to yield the trash contents. With the increasing acceptance of HVI readings in the domestic and international trading, there is a continued interest in the relationship between HVI trash and SA trash from cotton fiber customers and regulators. Due to the complexity of not only trash type, size, and its weight distribution but also the nature of HVI and SA tests, it is understandable that there are few studies available trying to bridge two types of trash readings and, apparently, this is a challenge. This study first investigated the correlations between two HVI trash readings, and revealed a general conversion of $HVI_{count}=104.5*HVI_{area}$ among low trash samples ($HVI_{area} \leq 0.40$). Then, correlations between the HVI and SA trash and also against AFIS trash were examined, and a stronger relationship between HVI and SA trash than between HVI and AFIS trash was observed. Next, the samples were sub-grouped subjectively according to the ratios of $HVI_{area}/SA_{visible}$ (or $HVI_{count}/SA_{visible}$), and from the plots with the least intercepts, it was proposed two general conversions of $SA_{visible} = 6.82*HVI_{area}$ and $SA_{visible} = 0.069*HVI_{count}$. In order to verify the likely conversion, NIR spectra were correlated with HVI_{area} readings. Considering the heterogeneous distribution of trashes in fibers and different sampling specimens between NIR spectral and HVI reference measurement, a 90% confidence interval was applied to exclude outlier samples from the calibration and validation sets. The recalibrated models revealed different response to validation samples in various subsets. Remarkably, the model from samples with the $HVI_{area}/SA_{visible}$ ratio of 0.12-0.18 suggested the highest r^2, RPD, and means/SEP, indicating the most appropriate references for the samples in this subset and echoing the earlier finding from simple descriptive approach of least intercept. Unquestionably, conversion constant might change with relative amount of trash size and type and also their weight distribution.

Introduction

Because of economic factors, virtually the entire cotton crop in the United States and Australia has been harvested by machines (Wakelyn et al., 2007). Mechanically harvested cottons contain 13-35% of foreign matters or plant-related contaminants and other irregularities (Funk et al., 2005). Considerable efforts have been made to remove the foreign matters (or trashes) as much as possible, during the subsequent ginning and cleaning practices (Anthony, 2007). However, it is impossible to separate all trashes from lint fibers with the implementation of cleaners at the ginning sites, as they could be mingled with lint fibers.

Presence of trashes at various amounts degrades the market values, and also influences the end-use qualities for yarn and fabric processing. Both human classer's inspection and high volume instrument (HVI) methods have been regulated by the USDA's Agricultural Marketing Service (AMS) for the classification of leaf grade and determination of trash content in lint cottons (USDA, 2005). In order to ensure a fair trading, the USDA's AMS has introduced the HVI measurements as a universal fiber quality indices to be implemented globally (Knowlton, 2002), because HVI is a automation-oriented testing equipment, and within 1~ 2 minutes, it provides several important fiber characteristics simultaneously, such as micronaire, strength, and color. HVI trash contents are generated by one of three HVI modules and represent the trash portion only detectable on samples' surface.

Over many years, extensive studies have been taken to develop a number of physical and optical instruments in measuring the trash contents (Gordon, 2007). The development can be categorized into two main methods: gravimetric based and geometric (or surface scanner) based. At present, representatives in the former group are Shirley analyzer (SA) and advanced fiber information system (AFIS), which separate the trash components by mechanical means and then collect information by weighing; while the ones in the latter group include the current

HVI lines and imaging devices (Xu et al., 1997), which perform optical surface scanning. Each of these instrumentals has its unique advantages and limitations, and the comparison between them is summarized in Table 1. For example, SA and AFIS are destructive in the analytical process, and the tested samples can not be used for repeatability and reproducibility purpose. Another concern with SA is labor-intensive and time-consuming (~15 min for one sample), while the one with AFIS is sample preparation that required in routine procedure. On the other hand, HVI can only assess the trash content in terms of particle count and percentage area on one sample's surface and, therefore, it does not yield any information about the weight of trash within the bulky samples. In addition, AFIS and HVI provide additional fiber properties other than trash contents, and SA has a small-scale cleaning function that makes it a useful tool for determining visible and invisible trash content in cottons.

Table 1. Comparison of 3 cotton trash measurement methods. [a]

	HVI	SA	AFIS
type	non-destructive	destructive	destructive
configuration	geometric	gravimetric	gravimetric
amount (g)	10	100	0.5
time (min.)	2	15	2
trash reading	particle & area	visible & invisible	visible foreign matter
other readings	yes		yes
cleaning effect		yes	
sample preparation	yes		yes

[a] To keep the common usage of trash readings from HVI, SA, and AFIS, direct numbers (instead of %) were used in this study. For example, the 3.65 value represented a sample with HVI area (or SA or AFIS) trash of 3.65%.

Due to the nature of inhomogeneous distribution of trash type and size, the concern of different sampling specimens during three independent measurements and also the availability of three instruments (especially, SA) at one cotton fiber research facility, there is little literature available to compare the trash readings among three methods. Meanwhile, because of relatively small sampling (~0.5 g) in AFIS procedure, trash readings from HVI and SA have been frequently cited. As the USDA's AMS has regulated the HVI indices as fiber quality characteristics globally, most challenge on HVI trash, from domestic and foreign customers, is how to understand the relationship between geometric based HVI trash and gravimetric based SA reading. Given the complexity of trash presence in lint fibers and also the nature of HVI and SA measurements, it is a challenge to unravel some kind of relationship between two types of trash determinations.

Near infrared (NIR) spectroscopy, a useful technique due to the speed, ease of application, and adaptability to on-line or off-line implementation, has been applied for the prediction of trash contents either from HVI reading (Liu et al., 2010a; Thomasson & Shearer, 1995) or SA and AFIS terms (Liu et al., 2010a; 2010b). For instance, Thomasson and Shearer (1995) reported the optimal NIR models for 8 cotton quality characteristics and observed the lowest R^2 value (0.60) for HVI trash component. In a recent study of evaluating 3 trash instrumentals by NIR technique, trash models built from HVI particle, HVI area, AFIS, and SA references in the 1100-2500 nm region were reported to have the R^2 of 0.80, 0.69, 0.82, and 0.82, respectively (Liu et al., 2010a). Even though the UV/visible/NIR models on visible trash and cotton fiber content in cotton waste were slightly improved (R^2=0.86) with the SA readings in the 1100-2496 nm region, it still showed the difficulty in precise and quantitative determination of visible trash and cotton fiber portions for quality control purpose (Liu et al., 2010b). Hence, the 90% confidence interval was implemented to remove outlier samples that exhibited larger differences between NIR predicted and measured references, and the recalibrated models revealed the feasibility of NIR technique in the determination of trash contents (Liu et al., 2010a; 2010b). Our strategy to exclude the outliers in developing reliable and robust NIR models might be reasonable, mainly because of (i) highly diversification of trash types and their heterogeneous distribution, (ii) lint fiber mingled in with visible trash and likely resulting in errors during SA reference determination (Montalvo and Mangialardi, 1983), (iii) near-surface characterization (~2.5 mm) of bulky samples in spectral reflectance acquisition (Haanstra et al., 1998), and (iv) varying sampling specimens between NIR spectral and reference measurements.

The objectives of this study were (1) to examine the correlation between 2 HVI trash readings, particle count (HVI_{count}) against percentage area (HVI_{area}), (2) to correlate the HVI trashes with visible trash content ($SA_{visible}$) from SA, (3) to relate the HVI trashes with visible foreign matter content ($AFIS_{VFM}$) from AFIS, (4) to sub-group the samples with the $HVI_{area}/SA_{visible}$ ratios and further to explore the relationship between HVI_{area} and $SA_{visible}$ readings for each subset, and (5) to verify the proposed relationship from independent NIR spectral response with the aid of partial least square (PLS) modeling.

Materials and Methods

Cotton Samples

A total of 406 lint cottons were collected over a 4-year span at ARS's Cotton Quality Research Station (Clemson, SC) to represent diverse distributions in cotton variety, growing years and locations. These samples were from normal cotton bales and contained low to medium level of trashes. They were well conditioned at a constant relative humidity of 65% and temperature of 22 ± 2 ºC, prior to subsequent trash content measurements and visible/NIR spectral collection.

Determination of Cotton Trash Contents

Cotton trash contents were measured in four reference indices from 3 instrumentals, namely, visible trash content ($SA_{visible}$, %) from SA (Shirley Developments, Ltd., Stockport, UK), visible foreign matter content ($AFIS_{VFM}$, %) from AFIS (Uster Technologies, Inc., Charlotte, NC), and HVI particle count (HVI_{count}) and percentage area (HVI_{area}, %) from HVI (Uster Technologies, Inc., Charlotte, NC). Following the standard procedures (ASTM, 1997), about 100, 0.5, and 10 g of lint cottons from same cotton bale but obviously different fractions were processed for trash contents by SA, AFIS, and HVI, respectively. Two readings from SA and HVI measurement and 3 replicates from AFIS measurement were averaged and then analyzed further.

Visible/NIR Reflectance Measurement

Visible/NIR reflectance spectra were acquired on a Foss XDS rapid content analyzer (Foss NIRSystems Inc., Laurel, MD). Approximately 10 g of cotton fibers (obvious different portion to reference determination) was pressed into a Foss coarse granular cell, which is rectangular with internal dimensions of 3.8 cm-wide x15.2 cm-long x 4.8 cm-depth. To keep a good contact between the cotton sample and optical window, 750 g of extra weight was loaded on the top of fiber samples consistently throughout the entire experiment. A background was recorded with a built internal reference before scanning the samples. The log (1/Reflectance) readings were acquired over the 400 - 2500 nm wavelength range at 0.5 nm interval and 32 scans. Three spectra were collected for each of cotton samples by repacking and then mean spectrum was available for model development.

Partial Least Squares (PLS) Models

The visible/NIR spectra were imported into the PLSplus/IQ package in Grams/AI (Version 7.01, Galactic Industrious Corp., Salem, NH; current part of Thermo Fisher Scientific) and were smoothed with a Savitzky-Golay function (polynomial = 2 and points =13), prior to calibration model development. During the PLS regression, two-thirds of spectra in one group were used for calibration equation development and the remaining one-third (every 3rd sample) spectra were used for model validation. To optimize the accuracy of PLS calibration models, the data were undergone different combinations of the spectral pretreatments. Leave-one-out cross-validation method was used, and the number of optimal factors selected for the PLS equation generally corresponded to the minimum of the predicted residual error sum of squares (PRESS). The saved regression equations were subsequently applied to the validation samples. Model accuracy and efficiency were assessed in the validation set on the basis of coefficient of determination (r^2), root mean square error of validation (SEP), and RPD (quotient of standard deviation (SD) to SEP). Usually, an optimal model should have higher r^2 and RPD and also lower SEP.

Results and Discussion

Descriptive Statistics of 3 Trash Measurements

(1) Relationship between HVI_{area} and HVI_{count}. Figure 1 shows the relationship between HVI_{area} and HVI_{count} for a set of 406 samples. It suggests a strong correlation (Pearson correlation, r, = 0.91), which is in very good agreement with Farag's observation on different data set in 2005 (r = 0.877). The scatter becomes more apparent as HVI_{area} and HVI_{count} (indicative of trash level) elevates, especially when HVI_{area} is greater than 0.40.

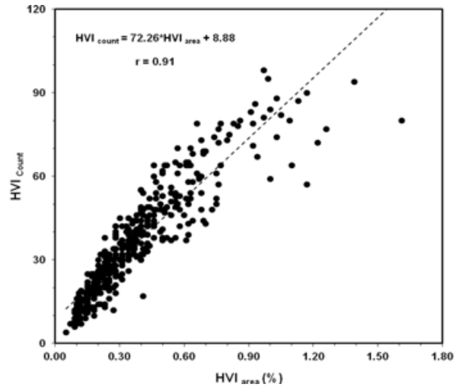
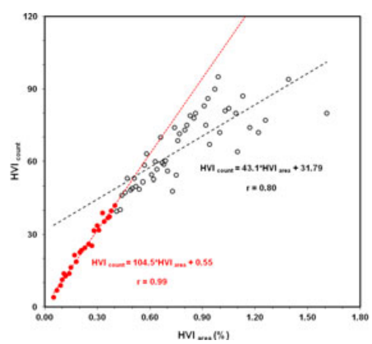


Figure1. Relationship between HVI_{area} and HVI_{count}.

If HVI_{count} was averaged for samples having the same HVI_{area} or HVI_{area} was averaged for samples having identical HVI_{count}, then resultant plots could be divided into two areas subjectively, with the boundary of HVI_{area} = 0.40 or HVI_{count} = 40 (Figure 2a & 2b). For example, they exhibit perfect linear relationships with smaller intercepts (closely passing the origin) and greater r (> 0.98) when $HVI_{area} \leq 0.40$ or $HVI_{count} \leq 40$ (or low trash cottons) than when HVI_{area} > 0.40 or HVI_{count} > 40 (or high trash cottons). Existence of more scatter samples and subsequently poorer correlation likely addresses the viewpoints of HVI trash measurement in high trash cottons. Nevertheless, it might conclude the relationship of HVI_{count}=104.5*HVI_{area} or HVI_{area} =0.0093*HVI_{count}, which is limited to low trash cottons.



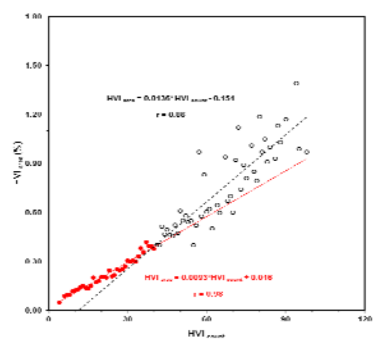
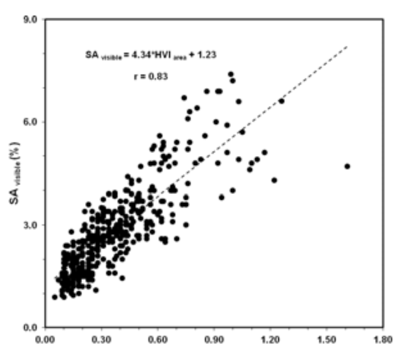


Figure 2a. HVI_{area} vs. averaged HVI_{count}. Figure 2b. HVI_{count} vs. averaged HVI_{area}.

(2) Relationship between HVI_{area} (or HVI_{count}) and $SA_{visible}$. Plots of both HVI_{area} vs. $SA_{visible}$ and HVI_{count} vs. $SA_{visible}$ (Figure 3a &b) reveal a strong correlation (r = 0.83 ~ 0.87), suggesting the good agreement of two testing in characterizing the cotton trash contents. The relationship between HVI_{area} and $SA_{visible}$ is very close to that of HVI_{count} and $SA_{visible}$ (0.83 vs. 0.87).



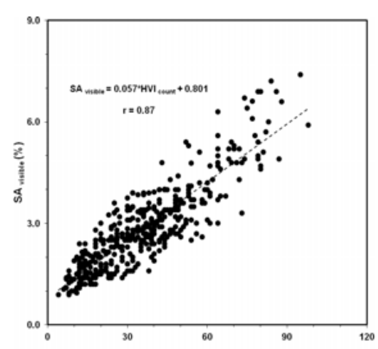
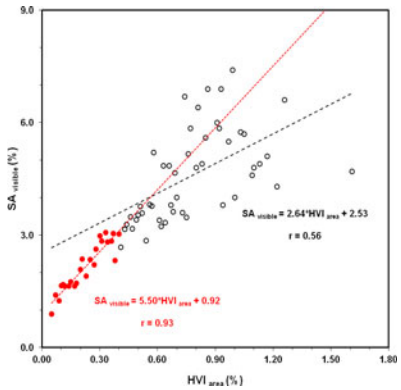


Figure 3a. HVI_{area} vs. $SA_{visible}$. Figure 3b. HVI_{count} vs. $SA_{visible}$.

If $SA_{visible}$ values were averaged for identical HVI_{area} or HVI_{count} (Figure 4a &4b), they yield better correlations (r > 0.93) in low trash cottons than in high trash cottons, as anticipated. Probably, relationship between HVI trash and

SA readings from Figure 3 or 4 could not be concluded, mostly because of large intercepts that were caused by the dissimilarities of samples between two determinations.



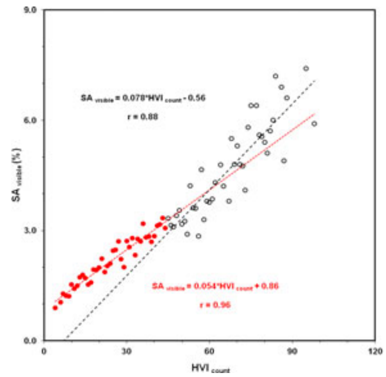
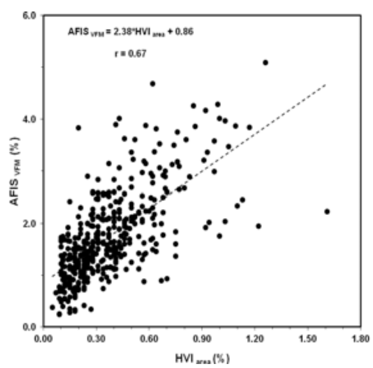


Figure 4a. HVI_{area} vs. averaged $SA_{visible}$. Figure 4b. HVI_{count} vs. averaged $SA_{visible}$.

(3) Relationship between HVI_{area} (or HVI_{count}) and $AFIS_{VFM}$. Though either HVI_{area} vs. $AFIS_{VFM}$ or HVI_{count} vs. $AFIS_{VFM}$ indicates a general trend in describing the trashes (Figure 5a & 6b), the correlations between the HVI and $AFIS_{VFM}$ (0.67~0.70) are much lower than those between the HVI and $SA_{visible}$ (0.83~0.87).



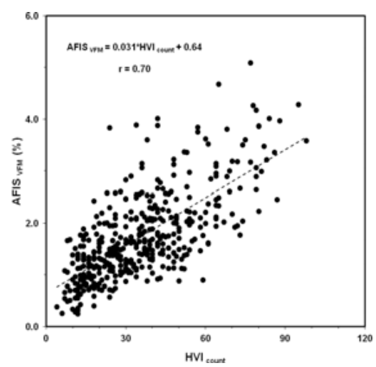
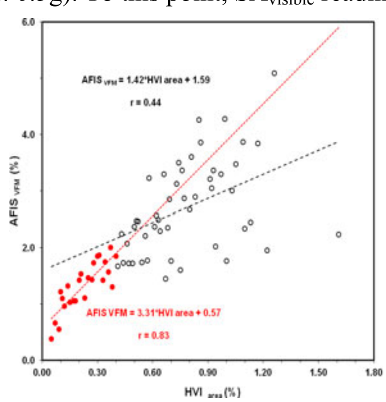


Figure 5a. HVI_{area} vs. $AFIS_{VFM}$. Figure 5b. HVI_{count} vs. $AFIS_{VFM}$.

Similarly, both HVI_{area} and HVI_{count} against averaged $AFIS_{VFM}$ show the correlations of < 0.90 in low trash cottons (Figure 6a & 6b), which are a little poorer than those between HVI_{area} or HVI_{count} against mean $SA_{Visible}$ (Figure 4). It is expected, as major reason might be due to large difference in sample amounts between HVI and AFIS measurement (10 g vs. 0.5g). To this point, $SA_{visible}$ readings were further explored in this study.



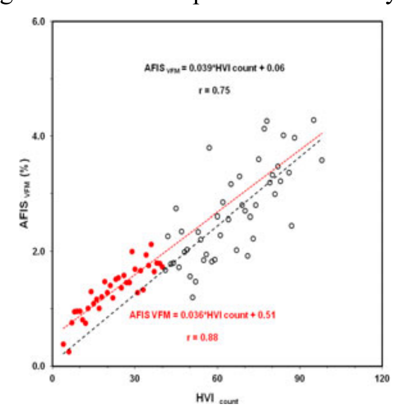


Figure 6a. HVI_{area} vs. averaged $AFIS_{VFM}$. Figure 6b. HVI_{count} vs. averaged $AFIS_{VFM}$.

Subjective Criteria to Determine the Relationship between HVI_{area} (or HVI_{count}) and $SA_{visible}$

Going back to Figure 3a, the ratios between HVI_{area} and $SA_{visible}$ were calculated first. Relying on the magnitude of HVI_{area} / $SA_{visible}$ ratios, the samples were subjectively divided into five subsets (Figure7) and resulted relationships from various subsets are characterized in Table 2.

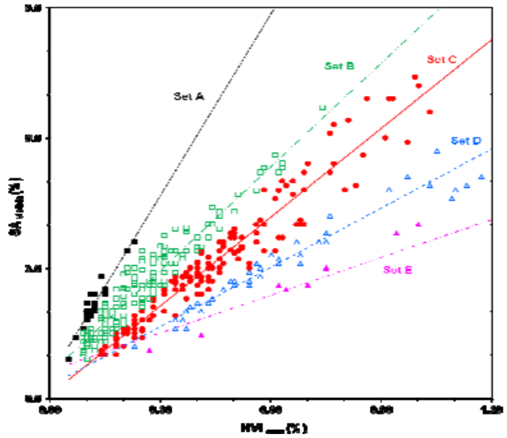


Figure 7. HVI_{area} vs. $SA_{visible}$ for 5 subjective subsets.

Table 2. Subjective criteria for sub-grouping the samples with HVI_{area} / $SA_{visible}$ ratios.

HVI_{area} / $SA_{visible}$ ratios	Relationship	r
< 0.06 (Set A)	$SA_{visible} = 13.94*HVI_{area} + 0.50$	0.95
0.06 ~ 0.12 (Set B)	$SA_{visible} = 7.97*HVI_{area} + 0.53$	0.95
0.12 ~ 0.18 (Set C)	$\mathbf{SA_{visible} = 6.82*HVI_{area} + 0.09}$	**0.97**
0.18 ~ 0.24 (Set D)	$SA_{visible} = 4.55*HVI_{area} + 0.28$	0.97
> 0.24 (Set E)	$SA_{visible} = 2.99*HVI_{area} + 0.69$	0.90

Table 2 suggests the higher correlation coefficients of >0.90 for 5 small subsets, as predicted, and also varying intercepts ranging from 0.09 to 0.69. Of the greatest attraction is the Set C that represents the $HVI_{area}/SA_{visible}$ ratio range of 0.12 to 0.18 and possesses the least intercept (0.09). Hence, it could be drawn the general conversion between HVI_{area} and $SA_{visible}$ with the equation of $SA_{visible} = 6.82*HVI_{area}$.

Undoubtedly, creation of 5 subsets leads to more discussions. However, minimum consideration of this concept lies in both least subgroups and least intercept (i.e., one correlation line closely passing the origin). If trash occurs uniformly and trash size/type are in average, $HVI_{area}/SA_{visible} < 0.12$ might suggest the dominance of non-leaf or large-size trashes, and vice versa if $HVI_{area}/SA_{visible} > 0.18$. In other words, either $HVI_{area}/SA_{visible} < 0.12$ or > 0.18 might imply the heterogeneous presence of trash types and sizes that likely cause the variations in trash contents between two types of instruments. To interpret the practical samples, an error (such as 5~10% or more) ought to be considered.

By the same procedure, the samples were subjectively classified into five classes with the HVI_{count} / $SA_{visible}$ ratios (Table 3), and the representation of Figure 3b is shown in Figure 8. Similar to Table 2, Table 3 reveals the higher correlation coefficients of > 0.97 and different intercepts among the 5 subsets. So, it might establish the relationship between HVI_{count} and $SA_{visible}$ with a formula of $SA_{visible} = 0.069*HVI_{count}$.

Table 3. Subjective criteria for classing the samples with HVI_{count} / $SA_{visible}$ ratios.

HVI_{count} / $SA_{visible}$ ratios	Relationship	r
< 6 (Set AA)	$SA_{visible} = 0.112*HVI_{count} + 0.496$	0.97
6 ~ 12 (Set BB)	$SA_{visible} = 0.085*HVI_{count} + 0.367$	0.98
12 ~ 18 (Set CC)	$\mathbf{SA_{visible} = 0.069*HVI_{count} + 0.106}$	**0.97**
18 ~ 24(Set DD)	$SA_{visible} = 0.058*HVI_{count} - 0.143$	0.98
> 24 (Set EE)	$SA_{visible} = 0.047*HVI_{count} - 0.069$	0.99

Meanwhile, from the respective equations of 5 subsets in Table 2 and 3, the conversions between HVI_{count} and HVI_{area} are estimated to be 124.4, 93.8, 98.9, 78.4, and 63.6. The value of 98.9 is very close to that 104.5 from the mean of HVI readings among low trash cottons, confirming the relationship between HVI_{count} and HVI_{area}.

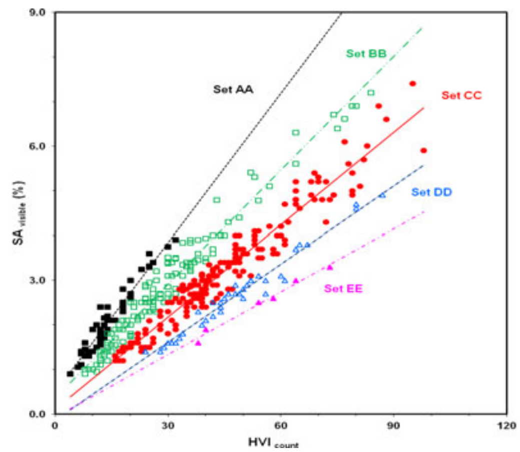


Figure 8. HVI_{count} vs. $SA_{visible}$ for 5 subjective subsets.

NIR Model Verification of Relationship between HVI_{area} and $SA_{visible}$

The mentioned strategy to establish the relationship between HVI_{count} (or HVI_{area}) and $SA_{visible}$ could be validated by independent NIR spectral acquisition. This is because there are significant NIR spectral difference between lint fibers and trashes (Liu et al., 2010b; Fortier et al., 2011); leading to the hypothesis that appropriate trash reference should have the best NIR model performance. In this attempt, HVI_{area} readings were used as a reference to compare with the NIR spectral response.

(1) Sample Distribution and Calibration/Validation Assignment. With the HVI_{area} / $SA_{visible}$ ratios, all samples were sub-grouped into respective classes (Table 4). Because of limited sample numbers, Set A and E were not analyzed. For either of 3 other sets, on the order of the smallest to the largest in HVI_{area}, every 3rd samples were selected to validate the calibration models that were built from the remaining samples.

Table 4. Sample distribution and assignment in each subset.

Subsets	Set A	Set B	Set C	Set D	Set E
Sample No.	20	183	152	40	11
Calibration No.		122	102	24	
Validation No.		61	50	16	

(2) NIR Models on HVI_{area} Readings. Typical log (1/R) spectra in the 1100-2500 nm NIR region of 3 cotton fibers with the HVI_{area} readings of 0.18, 0.56, and 0.92 (%) are shown in Figure 9. There are at least five intense and broad bands (1490, 1935, 2105, 2270, and 2320 nm), mainly due to the (1st and 2nd) overtones and combinations of OH and CH stretching vibrations of cotton cellulose (> 90% in total mass). Owing to relatively trash amounts, spectral distinctions among them are insignificant (Liu et al., 2010b).

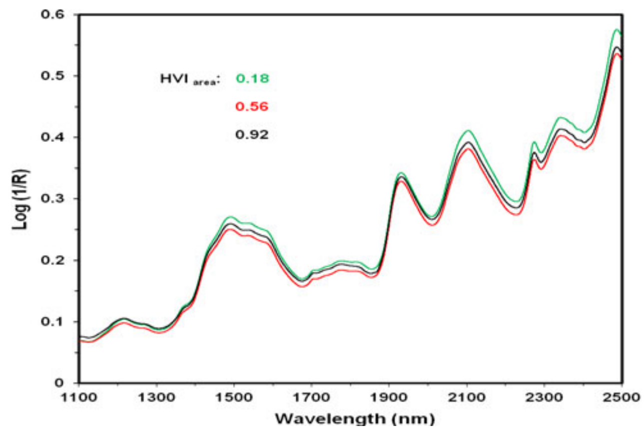


Figure 9. Typical NIR log (1/R) spectra of lint fibers.

The statistics of optimal results from individual subsets are tabulated for comparison (Table 5). These models were obtained from the combination of mean center and Savitzky-Golay 1st derivative (2 degrees and 13 points) spectral pre-processing in the 1105-2495 nm region. To facilitate the comparison of NIR model performance between individual subsets, RPD and mean/SEP, quotients of SD and mean of reference values to SEP in validation sets, were used and also included in Table 5. In general, r^2, RPD, and mean/SEP from Set B are very similar to those from Set C, and they are much better than ones from Set D.

Table 5. Optimal NIR model statistics on HVI_{area}.[a]

Subsets	Calibration set				Validation set					
	Range	SD	R^2	SEC	Range	SD	r^2	SEP	RPD	Mean/SEP
Set B	0.09-0.74	0.125	0.83	0.051	0.09-0.63	0.127	0.74	0.064	1.98	4.0
Set C	0.14-1.03	0.207	0.91	0.063	0.15-0.99	0.198	0.75	0.102	1.94	4.3
Set D	0.23-1.26	0.297	0.91	0.088	0.36-1.13	0.205	0.45	0.195	1.05	3.2
Set B[b]	***0.09-0.63***	***0.106***	***0.86***	***0.040***	***0.09-0.62***	***0.104***	***0.82***	***0.044***	***2.36***	***5.3***
Set C[b]	***0.14-1.03***	***0.197***	***0.95***	***0.045***	***0.15-0.92***	***0.186***	***0.90***	***0.062***	***3.00***	***6.7***
Set D[b]	***0.23-1.26***	***0.296***	***0.96***	***0.058***	***0.37-1.13***	***0.224***	***0.63***	***0.139***	***1.62***	***4.8***

[a]SD, standard deviation; SEC, root mean square error of calibration; SEP, root mean square error of prediction; RPD, ratio of SD to SEP. Mean/SEP, ratio of mean to SEP.
[b] By applying 90% confidence interval, samples with greater differences between NIR predicted and actual HVI_{area} values were excluded from the calibration and validation sets.

Even though samples in Set B, C, and D were pre-selected on the basis of two isolated testings, it might not ensure the homogeneous or close specimens for additional NIR measurement. Therefore, a 90% confidence interval was applied to exclude the outliers in three sets that had larger differences (or errors) between measured and NIR predicted HVI_{area} from calibration and validation sets, respectively. The models were recalibrated and the results are also compiled in Table 5 (***Bold Italic***). As expected, removal of outliers leads to the improvement in all model characteristics for each subset, and the difference among them might reflect different spectral response to the references in validation samples. Most notably, the model from Set C suggests the best model performance with the highest r^2, RPD, and mean/SEP. In other words, the best correlation might be related with the most appropriately determined references for HVI_{area} index. This observation is in well consistent with simple statistical approach of least intercept (Table 2).

Comparative scatter plots of measured and NIR predicted HVI_{area} from recreated models are shown in Figure 10. It suggests how well the NIR model predictions agree with the references from a separated measurement. With the impression, Set C exhibits a regression line more close to the 45-degree direction than Set B and D.

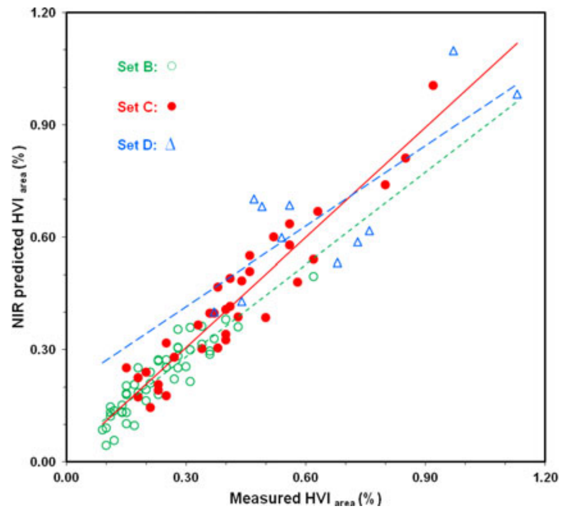


Figure10. Plots of measured vs. NIR predicted HVI_{area}.

Summary

Although a strong correlation exists between two HVI trash readings from identical specimens, their mean values yield a relationship of HVI_{count}=104.5*HVI_{area} in low trash cottons ($HVI_{area} \leq 0.40$).

It is reasonable to have scatter plots of HVI_{area} (or HVI_{count}) against $SA_{visible}$ and $AFIS_{VFM}$, despite of similar trend in describing trash contents. Overall, the correlations between HVI_{area} (or HVI_{count}) and $SA_{visible}$ are stronger than those between HVI_{area} (or HVI_{count}) and $AFIS_{VFM}$.

Regardless of apparent challenges from such factors as trash uniformity, type, size, and measuring methods, the samples were sub-grouped subjectively according to the ratios of $HVI_{area}/SA_{visible}$ (or $HVI_{count}/SA_{visible}$). From the respective plot of individual subsets, it was suggested two general conversions of $SA_{visible}$ = 6.82*HVI_{area} and $SA_{visible}$ = 0.069*HVI_{count}, which were obtained from the $HVI_{area}/SA_{visible}$ ratio range of 0.12 to 0.18 or $HVI_{count}/SA_{visible}$ ratio range of 12 to 18. Undoubtedly, these two conversion constants might change with relative amount of trash size and type and also their weight distribution.

To verify the proposed conversion between HVI_{area} and $SA_{visible}$, NIR spectra were correlated with HVI_{area} readings in three subsets. Considering the heterogeneous distribution of trashes in fibers and different sampling specimens between NIR spectral and HVI reference measurement, a 90% confidence interval was applied to exclude outlier samples from the calibration and validation sets. The redeveloped models exhibit different response to various references of validation samples in three subsets. Of interest is that the model from Set C (i.e., the $HVI_{area}/SA_{visible}$ ratio range of 0.12-0.18) suggests the highest r^2, RPD, and means/SEP, likely demonstrating the better determined references for the samples in this subset than those in other two sets (Set B and D).

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Disclaimer

Mention of a product or specific equipment does not constitute a guarantee or warranty by the U.S. Department of Agriculture and does not imply its approval to the exclusion of other products that may also be suitable.

Origination of this research—during the 2011 Beltwide Cotton Conference in Atlanta, Dr. James Knowlton talked his latest trip to China in the promotion of HVI measurement and mentioned one concern on the relationship between HVI trash and gravimetric method. The authors voluntarily performed this study by analyzing the data collected over a 4-year span at the house.

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